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The American University in Cairo



**School of Sciences and Engineering
Construction and Architectural Engineering**

Improving Project Performance Using Lean Construction in Egypt: A Proposed Framework

A thesis submitted in partial fulfillment of the requirements for the Degree of Master of Science in
Construction Engineering

**Marwa Gamal Swefie
Fall 2013**

**Supervisor
Dr. A. Samer Ezz El-Din**

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List of Abbreviations

Lean Construction	LC
Lean Construction Institute	LCI
Lean Project Delivery System	LPDS
Last Planner System	LPS
Value Added	VA
Non Value Added	NVA
Essential Non Value Added	ENVA
Integrated Project Delivery	IPD
Just-in-Time	JIT
Collaborative Master Target Programme	CMTP

Abstract

There are numerous challenges and problems facing the construction industry in Egypt. The main criterion for success of any construction project is to deliver the project without time or cost overrun. Lean Construction is a new management technique that has been successfully implemented in many countries to increase the probability of a project success. This research examines the effectiveness of implementing lean thinking on the performance of Egyptian construction projects. First, the current appreciation and awareness of lean construction within the Egyptian construction industry is determined through an actual survey within one of the largest construction firms in Egypt. It is concluded that 55% of the respondents are not aware about lean concept but have high potentials to use new management techniques/approaches to improve the projects' performance. The survey also presents some of the lean principles that are efficiently used in some of the construction projects in Egypt such as standardization, continuous improvement, housekeeping, customer focus, and reduce variability. However, some of the principles are still not fully implemented and need to be more considered in the Egyptian construction industry such as waste reduction, visual management, just-in-time, collaboration, benchmarking, and prefabrication. Second, a Proposed Lean Construction Framework is developed and several lean techniques are adapted. The developed framework consists of six items: 1) Process map 2) Current State Map 3) Waste Elimination 4) Used lean tools/techniques 5) Future State Map (for ongoing projects) 6) Ideal State Map (for new projects). The framework is applied on a Case Study for the ready mix concrete works of a garage area in an existing hotel project in Egypt to show its impact on the duration of certain processes in the project and on the non-value added activities. The three main phases of work examined in this case study are the preparation process (pre-execution), material delivery, and execution process of the ready mix concrete works. The data were collected through observations, monthly reports and schedules. The effectiveness and impact of some of the lean tools/techniques used in this research is evaluated based on previous implementations in similar countries to Egypt. In order to mimic the execution process of the ready mix concrete works in different projects conditions, concrete data is collected from 9 different projects in Egypt and is simulated in MS Excel to show the effect of the lean concepts on the duration of the execution process only. The results of applying the proposed framework to the current state for the three work phases of the project have showed significant improvements in time reduction, process efficiency and the number of the non-added value activities. It is found that the improvements in the project's performance of the ideal state (future projects) are more than those of the future state (for ongoing project). The proposed Lean Construction

Framework in this study is generic and can be applied to any type of work. However, the research results are based on one case study that only attributable and restricted to certain type of projects.

Chapter One

1. Introduction & Background

There are numerous challenges and problems facing the construction industry all over the world. Construction projects are famous for being over-budget, late and burdened with scope creep. Many of the problems facing the construction industry, such as delays, over-budgeting and poor quality, have been extensively discussed in the literature. The traditional construction management approach has been effective in solving some of these problems. The Construction Management has been defined as the overall planning of a project by allocating the appropriate resources to finish the project on time, at budget and at targeted quality. Figure 1.1 shows the “Scope triangle “which illustrates the relationship between the three tradeoffs in a project cost, time & quality. Successful project management can be achieved by bringing together the tasks and resources necessary to accomplish the project objectives and deliverables within the specified time constraints and within the planned budget.

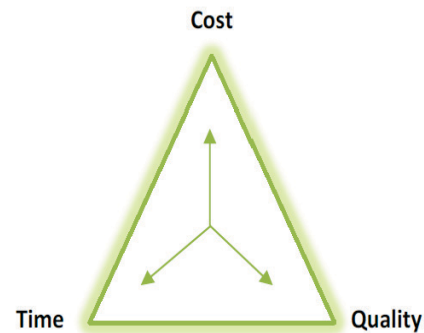


Figure 1. 1 - Scope Triangle

In Egypt, there are some serious challenges facing the construction sector. Being one of the major sectors in the Egyptian economy, construction and building sector has a significant impact on GDP, employment and investment contributing to at least 4.7% of the total GDP (Amcham 2003), (ISCG 2010). However, in the last two years and after the Egyptian revolution, many sectors suffered due to the unstable economy situation associated with the political risks in Egypt (Aref 2012). The construction sector has seen decline with 9.4% in the 1st Quarter of the Year 2012 and it continued to suffer the impacts of the unstable political situation (Aref 2012). This contraction, if continued, would have a deep impact on unemployment rates and many other industries. The main factors that are affecting the Egyptian construction sector can be classified as follows: construction companies, government policies and strategies, available resources, institutional backing and supporting industries (Amcham 2003). The prices and cost of the construction production factors such as labor, materials, machine utilization, transport, energy and other cost have changed over time, especially after the revolution. Figure 1.2 shows some of the price changes in the construction materials.

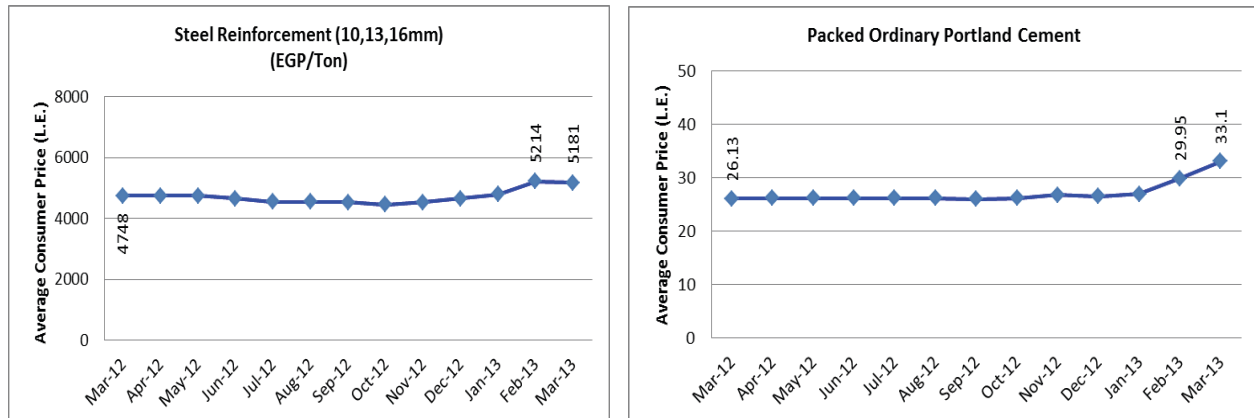


Figure 1. 2 - Price Changes in Construction Material (CAPMAS n.d.)

Therefore, a new methods and approaches should be developed and introduced to the industry in an attempt to overcome the damages occurred due to the current economic situation and to face all the new challenges that occurred after the revolution by minimizing all the non-add values to the industry.

Construction, being a complex industry, has motivated researchers to introduce new approaches and solutions to relieve the chronic problems in the industry. In this context, it was essential to enhance the traditional management methods in solving the problems, introduced by the Project Management Body of Knowledge (PMBOK) of the Project Management Institute (PMI), with novel management methods. These new methods include adoption of new technologies such as simulation, 3D modeling, Building Information Modeling (BIM) and new project management approach such as Lean Project Management.

1.1 Lean Construction versus Traditional Construction Project management approach

Lean approach is a new method of project management in construction industry. It is more efficient on complex projects with high uncertainties in addition to the fast track projects. There are several differences between the Lean Construction approach and the traditional project management approach. Following are some of these differences as discussed in the literature (more details will be presented in chapter 2) (Sicat 2012):

- The role of control in lean is to assure reliable workflow in contrary to traditional method which takes corrective actions after detecting variances.
- The main target of the lean approach is to maximize value by improving the whole process but in the traditional method optimization is for each activity separately.
- Lean is a pull-driven approach while traditional method is push-driven approach
- Reducing variations at early stages is one of the main aims of lean thinking while in the traditional approach it is not considered.

1.2 Brief Background on Lean Production

The Lean management philosophy was essentially derived from the Japanese manufacturing industry, mostly from the Toyota Production System (TPS) by Ohno, a young Engineer in Toyota (Holweg 2007). This system (TPS) was initially introduced by Japan after World War II when Japan required producing small batches of cars in many varieties in contrary to the Ford principle of mass production (same cars with large production runs) (Conte 2002). Toyota concluded that the principle of mass production is not efficient anymore, especially, after the collapse in sales that Toyota encountered and led to releasing large part of their workforce. Hence, they came up with new ideas and introduced the Toyota Production system, known as lean production (Ahrens 2006). Toyota's main purpose behind introducing this new concept, known as lean production, was to enhance production efficiency by producing high quality products with maximum value and at less cost (Jacobs 2010). The system was based on achieving a continuous production flow in order to reduce inventories. In essence, this was accompanied by eliminating activities that add no value to the final product, namely wastes which obtained a system that gave Toyota high performance levels (Conte 2002). In lean manufacturing, all the lean techniques are employed to continuously identify and remove the wastes from the system (Badurdeen 2006). Lean production system aims to meet customer requirements by delivering the product instantly and with no intermediate inventories (G. A. Howell, What is Lean Construction 1999). The manufacturing process has seen noticeable improvements and development after applying lean production principles to the industry (Zimmer 2005).

1.3 From Lean Manufacturing to Lean Construction

Construction processes are becoming much more complex and therefore a coherent management approach should be developed to solve the chronic problems and difficulties of the construction projects. Lean Construction (LC) was introduced and defined by The

Lean Construction Institute (LCI) as “a production-management-based approach to project delivery-a new way to design and build capital facilities”. Having seen intrinsic improvements in manufacturing, implications of lean production principles to the construction changed the method of work done through the delivery process. The main purpose of lean production system is to maximize value and minimize waste by using the appropriate lean techniques (Blakey 2008). Despite the significant differences between the features of construction and manufacturing, they almost share the same goals and pursue same principles such as system optimization through collaboration, continuous improvement, focus on customer satisfaction, work flow by eliminating obstacles and non-added values and creating pull production.

Implementing lean production philosophy to Construction presents challenges due to the significant differences in the physical characteristics of the end product of manufacturing and construction. Yet, it meant to be a step forward as it presents a lot of potentials to improve the industry. One-of-a-kind production, site production and complexity are some of the features that distinguish construction from manufacturing (O. Salem, et al. 2006). These features were described in previous researches as follows: On-site production: Construction is site-position manufacturing where the production process (installation & erection) is carried out at the final site which increases the value of the product. Also, the contractor must assure high-quality standards for the erected components on site which is mostly affected by site conditions (O. Salem, et al. 2006) (Koskela, Application Of The New Production Philosophy To Construction 1992); One-of-a-kind production: The frequency of customizing products in construction is much more higher than in manufacturing where the customers play an important role in customization/change throughout the course of a project. In contrary, manufacturing are known for using specialized equipment to standardize the items accepting very low level of customizations by retailers (O. Salem, et al. 2006) (Koskela, Application Of The New Production Philosophy To Construction 1992); Complexity: Construction process is complicated, unique and dynamic where each project is a new task accompanied by different resources, ideas and initial design with variable specifications. In contrast, in manufacturing, the production process is optimized by using specialized facilities with appropriate technology to ensure the reliable flow of the product (O. Salem, et al. 2006). These characteristics together cause a lot of uncertainties in the production process. The climatic and soil conditions, coordination between different trades and the customer changes are some of the uncertainties that may encounter any project causing significant impact on the time and cost of the project (O. Salem, et al. 2006).

Despite the differences between Construction and manufacturing industries, they are both aiming to deliver a competitive product in the shortest time possible with maximum value

and quality and at less cost (Zimmer 2005). Given the aforementioned resemblances, then the applicability of lean production in construction was considered. Notwithstanding, each industry has its own ways to achieve the target of Lean (O. Salem, et al. 2006).

1.3.1 Implementing Lean Manufacturing Techniques to Construction

Lean approach is determined by applying the relevant techniques to the main activities of the process. Design, supply and manufacturing are the basic activities of the lean organization (O. Salem, et al. 2006). The main goals of these principles, as introduced by TPS, are cost reduction, quality assurance and developing people/partners to ensure sustainable growth of the system (O. Salem, et al. 2006).

Japanese manufacturers, especially Toyota Co., have developed the principles of lean production. Liker introduced the 14 principles that create the Toyota way and organized them in four wide categories known as the four “P’s” :1) Philosophy, 2) Right Process lead to Right Results 3) Developing Your People/Partners, and 4) Solving Root Problems (Liker 2004). Toyota Way is about creating continuous improvements within an organization. Essentially, TPS is famous for its focus on waste reduction by reducing non-value added activities. Toyota identifies seven main types of waste and Liker added an eighth: 1) overproduction 2) waiting 3) unnecessary transport 4) over processing 5) Excess inventory 6) unnecessary movement 7) defects 8) unused employee creativity (Liker 2004).

The shortcomings in the existing planning, execution, and control models were demonstrated by Koskela and Howell while introducing new conceptual models of project management theory. They concluded that the traditional tools, as introduced in the PMBOK (work breakdown structure, CPM, and earned value management), failed to deliver projects’ on-time, at budget and at desired quality and argued that that these tools are unable to manage project-based production systems (Abdelhamid 2004).

The term “Lean Construction” was introduced in 1993 by the International Group for Lean Construction in its first meeting that was hosted by Lauri Koskela in Finland (Gleeson 2007) (Ballard and Howell, Lean project management 2003). The lean project delivery system was developed by the Lean Construction Institute (LCI)/Ballard. The basic idea or domain of LPDS is the project-based production systems. Ballard classified the LPDS into four interconnected modules: project definition, lean design, lean supply, and lean assembly (G. Ballard, Lean Project Delivery System 2000). Following is some of the lean production techniques as introduced in the literature: Flow Variability, Process Variability, Continuous Improvement, and Transparency (O. Salem, et al. 2006). Several countries

started to use and incorporate lean concepts and techniques in the construction industry such as USA, UK, Finland, Denmark, Singapore, Korea, Australia, Brazil, Chile, Peru, Ecuador and Venezuela (Ballard and Howell, Lean project management 2003).

1.4 Problem Statement

The conventional project management approach in construction is not appropriate for complex projects anymore due to the several deficiencies of the traditional method illustrated in chapter 2. The traditional Monitoring and Control under the PMBOK® Guide, 4th Edition, corresponds to a reactive approach more than a proactive one in which actions are only taken after the problems are appeared instead of preventing their occurrence.

The Lean thinking is still not widely applied among the construction organizations and projects in Egypt. The emphasis within lean construction literature has mainly been focused on data collected from construction projects outside Egypt. Limited lean construction studies were conducted in Egypt concerning the applicability of the lean principles on construction projects.

1.5 Objective

The main aim of the thesis is to improve the performance of construction building projects in Egypt by applying the appropriate lean concepts to the process from the Contractor's perspective. This can be achieved through the following:

1. Determining the current appreciation and awareness of lean construction within the Egyptian construction industry.
2. Developing a framework to show the effectiveness of implementing Lean concepts to the conventional management approach (PMBOK) in the Egyptian construction industry. It also shows how various aspects of lean thinking can be implemented in a construction project.
3. Verifying the proposed framework by applying it to a case study in Egypt showing the impact of using lean construction concepts on the duration of the ready-mix concrete activities.
4. Enhancing the prospect of the Project Control process from being a reactive approach to a proactive one by applying lean concepts.

1.6 Research Methodology

The research method used to achieve the objectives of this thesis is based on the following steps:

1. Literature Review to show the realized benefits from applying lean concepts to construction in different projects from different countries
2. An actual survey (on-site and off-site interviews) to identify the current appreciation and awareness of lean construction within the Egyptian construction industry.
3. Proposed Framework for applying Lean Construction in Egypt (practical guidelines)
4. Apply the proposed lean construction framework on a case study to show the impact of implementing lean concepts on the project performance
5. Simulation model for a part of the framework to show all the possible improvements to the project

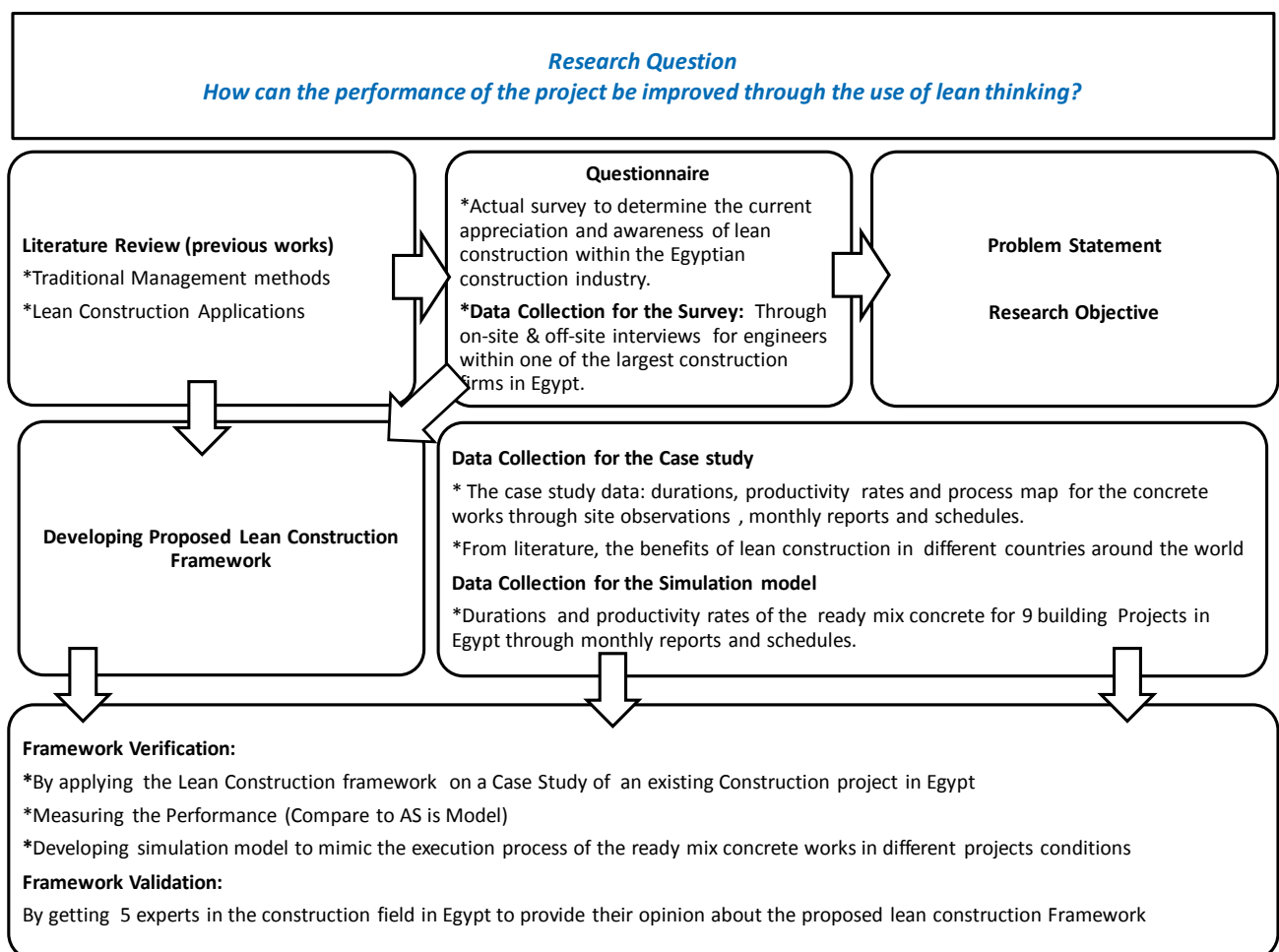


Figure 1. 3 - Research Methodology

These steps are further explained in the following section and are illustrated in figure 1.3.

1. Literature Review

The literature review conducted in this research focused on the several applications of lean principles in construction industry. The benefits of using lean approach in different countries outside Egypt were also addressed. In addition, criticism for the traditional management approach pursued by the PMBOK was discussed, especially, the Monitoring and Controlling phase being the backbone for the whole construction process. Based on this, the difference between the conventional management approach and lean approach was addressed to show the deficiencies of the conventional approach in comparison with the lean thinking.

2. Questionnaire

For the purpose of achieving the goal of this research, a questionnaire was conducted in one of the leading construction companies in Egypt. This questionnaire was used to investigate the main factors impacting the construction projects performance and the employees 'understanding regarding the lean thinking/techniques in the Egyptian construction industry.

The questionnaire is classified into 3 main sections as follows:

- Section (A): is structured to investigate general information and background about the respondents' experience.
- Section (B): is structured to identify the factors affecting the overall performance of the project in current practice and the methods adopted to reduce these negative impacts.
- Section (C): is structured to examine the respondents' awareness about lean techniques and their applications in the Egyptian construction industry.

3. Problem Formulation

The problem statement was formulated after conducting an initial research in the literature and in the Egyptian construction industry through a survey. The literature and the survey showed that there is lack of awareness of lean thinking in the construction industry in Egypt. Most of the scholarly studies were based on data collected outside Egypt and very few studied was conducted in Egypt regarding lean thinking in Construction.

4. Thesis Objective

The main aim of the thesis is to improve the performance of construction building projects in Egypt by applying the appropriate lean concepts to the process from the Contractor's perspective.

5. Framework Development

A Framework was developed to show the effectiveness of implementing Lean concepts to the conventional management approach in the Egyptian construction industry. It also shows how various aspects of lean thinking can be implemented in a construction project. The proposed framework showed the practical guide lines that can be followed in order for the lean thinking to be appropriately applied to the construction industry.

6. Framework Verification: A Case Study

For the purpose of framework verification, actual data from an existing project was gathered (case study) and analyzed to show the impact of using lean concepts on the overall duration of certain process. Case studies are a suitable way to study and investigate the current management approach in projects (Merschbrock 2009).

The framework application focused on the preparation phase, material delivery and execution phase of the ready mix concrete works (including all the relevant works such as shuttering, reinforcement and pouring). The choice of this scope of work (concrete) was based on the 80/20 rule as concrete works usually represents a considerable percentage of the project cost and duration in most of the projects in Egypt.

The collected data shows the current work activities and map the real process of concrete work activities of construction project in one of the largest construction firms in Egypt. The necessary quantitative data for preparation and execution process of the concrete works was collected from site observations and the schedule updates. The collected data was analyzed and the main factors impacting the performance were identified. Based on this data, the lean construction framework was applied to the current process and the effectiveness of implementing lean concepts to the process was identified.

7. Simulation Model

To ensure that the framework accurately represents the real process, a customized simulation model was developed in Excel to show the effect of the lean principles on the project duration for part of the works described in the framework. The duration of the concrete work activities was collected from 9 projects to provide basis for such model. Random numbers of the projects duration were generated using normal distribution on MS Excel software. The project activities (variables) were simulated to show the impact of each variable on the output results (project duration) and changes to as is model were identified. Then, the lean principles were introduced to both models to show the effect of different lean techniques on the overall duration of the concrete activities.

8. Data Collection

8.1 Survey

A questionnaire was conducted and sent to 25 respondents in different projects within the same organization. Only 20 out of 25 responded to the questionnaire. The main purpose of this questionnaire is to measure the awareness of employees about Lean construction in Egypt. The examined sample was taken from one of the two biggest construction companies in Egypt, being a pioneer in the construction field. The details and the analysis of the questionnaire are illustrated in Chapter three.

8.2 Case Study Data

The quantitative data of the case study was provided by the Main Contractor. The concerned data was the preparation phase, material delivery phase and execution phases. The durations and productivity for all the relevant activities was collected. The data collection included also the process maps of the aforesaid activities. These data was collected from the approved Baseline schedules, daily reports and submittal logs. Based on the literature, the lean approach is more efficient in the fast track, uncertain and complex projects; hence, the case study was chosen based on this. The case study description: Existing Hotel project located near downtown in Cairo, Egypt. It consists of one existing building which is the main building which consists of 144 rooms and 12 floors and three new building: swimming pool, Garage area and Ballroom. The research will focus on the concrete process of the Garage Area. The details of the Garage Area are illustrated in Chapter four.

8.3 Lean benefits from Literature

Since lean construction is new to the construction sector in Egypt, an overview of lean benefits from previous works outside Egypt was highlighted. The impact of lean approach on the duration and productivity of projects outside Egypt was addressed. These impacts were then filtered and the most convenient results, from countries that are almost similar to Egypt circumstances, were chosen to show the impact of such principles on the construction process of the chosen case study.

9. Framework Validation

For the purpose of framework validation, a set of interviews were conducted with 5 experts in the construction field in Egypt. They were asked to provide their opinion about the applicability and efficiency of the proposed lean construction Framework. The analysis and results of the interviews are illustrated in chapter 5.

1.7 Thesis Overview

The thesis consists of six chapters as follows:

Chapter two presents an extensive literature review for the traditional construction management approach and how the lean construction emerged and applied to the industry.

Chapter three demonstrates on the questionnaire analysis and results regarding the Egyptian market awareness of the Lean thinking in the construction industry. In addition, it focuses on the relation between the lean principles and the main factors affecting the projects' performance in Egypt.

Chapter four introduces detailed description for the Framework development that was used to achieve the research objective. This chapter includes description and analysis for the used case study. It also includes customized simulation model for part of the works addressed in the framework.

Chapter five shows the study results of the proposed framework and the simulation model.

Chapter six presents the conclusions and recommendations for future research.

Chapter Two

2. Literature Review

Construction is a very complicated industry that requires rigorous systems to deliver the project on timely, efficient and effective manner. The schedule and cost overrun are common in most of the construction projects. Therefore, the main criterion for success of any construction project, regardless its size or complexity is to deliver the project without time or cost overrun. Several causes of the cost and time overrun were identified in the literature. Rahman et al. present in their research the causes related to construction resources which considerably causing cost overrun. The resource related factors as identified in the literature includes: material, manpower, equipment and finance (Rahman, Ismail A.; Memon, Aftab H.; T.A.Karim, Ahmad 2013). Table 2.1 shows list for the causes identified by Rahman, et al. 2013; Olawale and Sun 2010.

Table 2. 1 - Factors causing construction cost and time overrun (Rahman, Ismail A.; Memon, Aftab H.; T.A.Karim, Ahmad 2013) (Olawale and Sun 2010)

Category	Factors for Time and cost overrun
Material	Fluctuation of prices of materials
	Shortages of materials
	Changes in material specification and type
	Delay in delivery of materials
	Dependency on imported materials
Manpower	High cost of labor
	Shortage of skilled labor
	Severe overtime
	Labor productivity
Money	Financial difficulties of owner
	Delay payment to supplier/subcontractor
	Delay in progress payment by owner
	Cash flow and financial difficulties faced by contractors
	Poor financial control on site

Machinery	Equipment availability and failure Late delivery of equipment Insufficient number of equipment
Unforeseeable conditions	Unpredictable weather conditions Risk and uncertainty associated with projects
Management	Lack of proper training and experience of PM Complexity of works Lack of appropriate software
Engineering/Contract	Design changes Discrepancies in contract documentation
Project Stakeholders	Conflict between project parties Non-performance of subcontractors and suppliers

Many of the causes of cost and schedule overrun can be avoided by incorporating various changes to the traditional management approach or by applying new management thinking to the industry.

2.1 Deficiencies in Traditional Project Management Method

Koskela and Howell (2000), in their prior researches, highlighted the reasons behind introducing novel methods in construction management. In their researches, they criticized the current management practice and argued that this approach is inadequate and should be reformed to keep pace with the complexity and uncertainty of the projects (Howell and Koskela, Reforming Project Management: The Role of Lean Construction 2000). Before showing the shortcomings of the traditional project management approach, the following paragraph will present a brief about its definition and contents.



Figure 2. 1 - Project Management Triangle

The Project Management Body of Knowledge (PMBOK) of the Project Management Institute (PMI) defined project management as (R.Duncan 1996):

“Project Management is the application of knowledge skills tools, and techniques to project activities in order to meet or exceed stakeholder needs and expectations from a project. Meeting or exceeding stakeholder needs and expectations invariably involves balancing competing demands among:

- Scope, time, cost and quality
- Stakeholders with differing needs and expectations
- Identified requirements (needs) and unidentified requirements (expectations)”

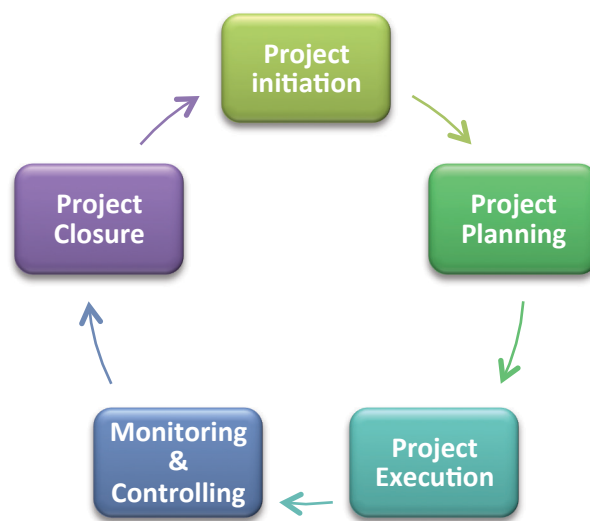


Figure 2. 2 – Project Management Life cycle (PMI 2008)

The Project Management Body of Knowledge (PMBOK) provides guidance for the typical project life cycle. The phases of the project life cycle as introduced in the PMBOK are as follows:

- 1) Initiation Process
- 2) Planning Process
- 3) Execution Process
- 4) Monitoring & Controlling Process
- 5) Closing process

Koskela and Howell (2000) claimed that the deficiencies in the current project management are due to flawed assumptions and theories. The assumptions include several deficient perceptions such as low uncertainties as to scope; activities relationship and dependencies are simple, controlling activity standards will assure outcomes. Morris described the theory of project management as a discipline of applying the transformation model of production used previously in manufacturing (Howell and Koskela, Reforming Project Management: The Role of Lean Construction 2000). Theoretical deficiencies can be briefed as follows: that there are other characteristics in production besides transformations that can make the output valuable, resources usage efficient and customer requirements are met in the best manner (Howell and Koskela, Reforming Project Management: The Role of Lean Construction 2000). It was argued that improvements to the current practice of management can be achieved by applying the production management approach including not only transformation but management of workflow and value generating process as well. Hence, lean production theory and principles were considered to be applied to construction (Howell and Koskela, Reforming Project Management: The Role of Lean Construction 2000). Table 2.2 illustrates the Ingredients of the new and theoretical foundation of project management.

Table 2. 2 - The ingredients of the new and underlying theories of project management

(Koskela and Howell, The Theory of Project Management: Explanation to Novel Methods 2002)

Subject of Theory		Underlying theory of project management	New theoretical foundation of project management
Project		Transformation (Input & Output)	Transformation Flow Value generation
Management	Planning	Management-as-planning	Management-as-planning Management-as-organizing
	Execution	Classical communication theory	Classical communication theory Language action perspective
	Control	Thermostat model	Thermostat model Scientific experimental model

Koskela and Howell (2002) believed that the underlying theory of the conventional construction project management practice is obsolete; hence, it should be reformed. They addressed the problems occurred as a result of the conventional methods flaws such as: "Project management has not achieved the goals set to it: it does not perform in a satisfactory way. In small, simple and slow projects, the theory-associated problems could be solved informally and without wider penalties. However, in the present big, complex, and speedy projects, traditional project management is simply counterproductive; it

creates self-inflicted problems that seriously undermine performance.” (Koskela and and Howell, The underlying Theory of project management is obsolete 2002). Therefore, it became crucial in construction industry to search for non-conventional methods and new management thinking to achieve the maximum value with minimum waste, time, and cost. Table 2.3 shows the differences between the traditional approach and Lean approach as addressed in the literature

Table 2. 3 - Differences between the traditional approach and the Lean approach (H. G. Ballard 2000, Sicat 2012, G. Ballard, 2000, Howell, 1999)

Activity	Traditional PM Approach	Lean Construction Approach
Control	Project control represented in monitoring the performance (schedule and cost) and take corrective actions after detecting negative variances as shown in figure 2.3 and 2.4 (H. G. Ballard 2000).	The role of project control is to assure reliable workflow by measuring and improving the system Performance (Sicat 2012)
Performance	In the traditional approach, all the efforts of the management are concentrated on optimizing each activity separately, thus, reducing overall performance (Sicat 2012)	The main target is maximizing value with minimum waste at the project level to assure reliable workflow (Sicat 2012) (G. Ballard, Lean Project Delivery System 2000).
Value	Considering less cost as value. Also, the customer has to define all his requirements at the outset of the project regardless the change in markets and the new technologies (Sicat 2012).	Project is managed as a value generating process where the customer satisfaction is created and developed over the course of the project (G. A. Howell, What is Lean Construction 1999).
Work techniques	Push-driven schedules are used to release information and material (Sicat 2012). (e.g. material is ordered to a pre-determined schedule to arrive on site before the work is carried out. If the stock is not used, the	Pull-driven schedules control the information and material flow (H. G. Ballard 2000). etc. The team works backwards (pulls) from the end date to the start of the phase to identify the activities

	supplier continues to deliver to schedule.)	necessary to reach the “end” target. (building only what is needed, when it is needed, with no waste in the process)
Centralization	Decision making is centralized through one manager in sometimes.	Decision making through transparency by getting project participants involved in the production control system and empowering them to take action (Sicat 2012) (H. G. Ballard 2000).
Under loading	PMI does not consider adjustments	Production unit capacity is adjusted as well as inventory to be able to absorb variation (H. G. Ballard 2000)
Variations	Variation’s mitigation and management is not considered	Attempts to mitigate variation in respect of end product quality and work rate (H. G. Ballard 2000)
Collaboration	Such policy is not applied in the traditional methods	LC gives continuing support to suppliers by developing new commercial contracts which gave the suppliers incentives for reliable work flow and for participating in the overall product improvement (G. A. Howell, What is Lean Construction 1999).
Transparency	Transparency methods are not considered in traditional management methods.	Increasing transparency between all the project’s stakeholders to allow people make decisions reducing the need of central management (G. A. Howell, What is Lean Construction 1999).
Continuous Improvement	Traditional method does not consider continuous improvement so much.	LC considers continuous improvement in the process and workflow (G. A. Howell, What is Lean Construction 1999).

**Interactions
and
dependencies**

Managing the combined effect of dependence and variation on activities is important as it affects the time and cost of any project (G. A. Howell, What is Lean Construction 1999).



Figure 2. 3 – Quality Control Process in the traditional method

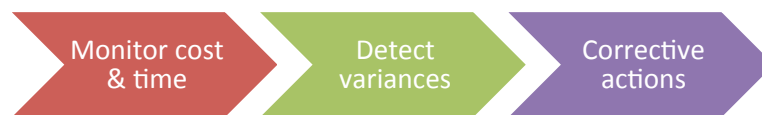


Figure 2. 4 – Project Control Process in the traditional method

2.2 Lean construction – a project approach

Construction industry is suffering from various problems such as low productivity, insufficient quality, poor safety, time and cost overruns minimizing the value of the end product as shown in figure 2.5. The adoption of Lean manufacturing principles to the construction is an innovative approach for managing and improving construction processes by reducing cost and maximizing value considering customer needs (Koskela et al. 2002).

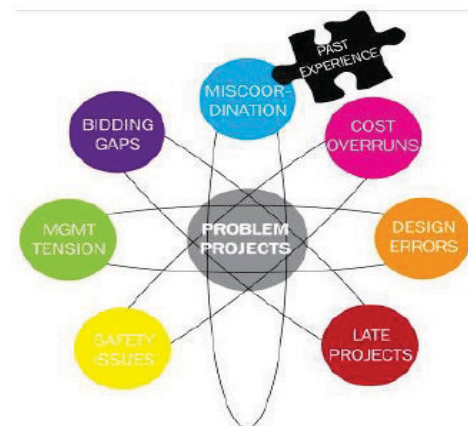


Figure 2. 5 - Project Problems (Howell and Lichtig 2008)

Same as manufacturing principles, minimizing waste at early stages lead to a better quality and thus successful project in terms of time and cost. The manufacturing process has seen noticeable improvements and development after applying lean principles to the industry. The main attribute of large construction projects nowadays is the complexity and uncertainty. Traditional project management methods are more adequate for simple projects. These traditional methods will not be able to comply with the sophisticated projects requirements' due to the various interactions between activities (Bosca' 2012). In an attempt to find alternative approach to deal with the projects complexity and problems, Lauri Koskela (1992), who is a pioneer in introducing lean construction, used the lean thinking approach. He argued that traditional thinking of construction management focuses on conversion activities and does not pay attention to flow and value. He described wastes associated with the construction process as waste of materials and non-value added activities that may lead to waste such as delays, transportation of materials and others (Senaratne and Wijesiri 2008). Some researches that were conducted in the United States and Europe showed that waste can be generated during the flow process of construction. Following is the percentages of consumed cost due to flow deficiency according to koskela (1992) findings: 'non-conformance quality costs' consume 12% of total project cost; 'poor materials management' causes 10- 12% of total labor cost; 'time used for non-value adding activities' amounts to 2/3 of total project time; and 'lack of safety' amounts to 6% of total project cost (Senaratne and Wijesiri 2008). By eliminating cost-consuming flow activities, Lean approach provides potential advantages for cost reduction when successfully implemented in a construction company and can be considered as a cost leadership (Senaratne and Wijesiri 2008). One of the main challenges that facing implementation of lean construction, is its acceptability by the workforce. In this regard, implementation of this concept should be done in a proper way and without adding any burdens on the workforce and by convincing them that this approach is a way to enhance the organization profit (Senaratne and Wijesiri 2008).

Although there are many common elements between Lean manufacturing and lean construction techniques, not all lean production theories can fully be implemented in the construction industry. There are obvious differences between Manufacturing plants and construction sites (O. Salem, et al. 2006). From the literature, lean principles were found to be affecting the construction process efficiently. The construction process has seen intrinsic improvements in terms of quality and cost by addressing lean principles. The project is said to be "lean" when it is delivered with minimum waste and maximum value.

2.2.1 Waste Elimination

Wastes usually result from poorly managed systems and process that result in excessive time and cost. The level of waste associated with construction projects has been reported to be as much as 50 percent, and is attributed to inefficiencies through design, mobilization, construction and maintenance activities (O'Connor and Swain 2013).

The main purpose of lean construction is waste reduction (Sacks, et al. 2010). The challenge in waste reduction is determining the methodology of identifying waste in construction projects. Waste elimination should start from the design stage. In order to eliminate the waste in the construction process, types of wastes should be identified. The 8 types of wastes were introduced in the literature as follows (Garrett and Lee 2011):

- Overproduction
- Waiting
- Transportation
- Unnecessary processes
- Inventory
- Unneeded movement
- Defects
- Underutilized people

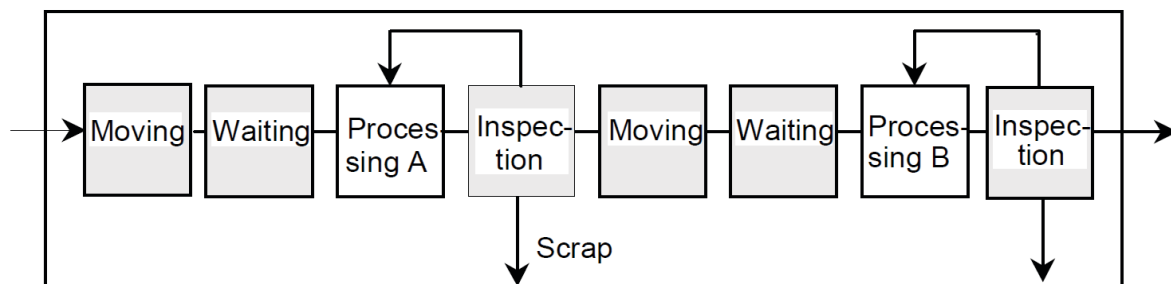


Figure 2. 6 - Production as a flow process and the shaded boxes are the non-value adding activities (Koskela, An exploration towards a production theory and its application to construction 2000)

Figure 2.6 shows the several wastes within the production process which prevent the work from flowing smoothly. The aforesaid types of wastes can be eliminated or reduced by considering the relevant lean techniques. Some of which are housekeeping, just-in-time (JIT) delivery, information technology and pre-fabrication (Eriksson 2010). Nevertheless, Sacks et al. (2009) focused on the notion of process transparency which leads eventually to

waste reduction as visualization helps to reduce uncertainties (Sacks, Treckmann and Rozenfeld 2009). In construction industry, waste generation is not only confined to that resulted from execution (material waste, productivity loss...) but extends to the flow of information and documentation. Garrett and Lee (2011) addressed the types of waste and its possible causes to the submittal review process in construction project (Garrett and Lee 2011). Thus, waste reduction became an objective by itself more than a tool when thoroughly collaborates with other lean principles.

2.2.2 Lean Project Delivery System

Production is defined as designing and making things. Projects are considered temporary production systems which are interrelated with other production systems from which the project is provided by supplies, resources and information. The primary goals of any production system is to deliver the product while maximizing value and minimizing waste. Construction is one among many types of project-based production systems (Ballard and Howell, Lean project management 2003).

Lean Project Delivery System (LPDS) is a new construction management approach inspired by the Toyota Production System (TPS) (Michel n.d.). This system based on the principles of applying the theory of lean production to construction projects - a project-based production system. LPDS was introduced by LCI (Lean Construction Institute) as part of their mission in developing an innovative way to design and build capital facilities. LCI developed the Lean Project Delivery System (LPDS) that applies lean construction principles and tools to facilitate planning and control, maximize value and minimize waste throughout the construction process. (G. Ballard, Lean Project Delivery System 2000)

The main focus of this system was to improve the entire delivery system and its main components (e.g. design, assembly, use) instead of optimizing each sub process separately. Different to the project phases of the traditional method, LPDS divided the project into 5 interconnecting phases from project definition to design to supply, assembly and use (See figure 2.8) (G. Ballard, Lean Project Delivery System 2000) (Ballard and Howell, Lean project management 2003).

Project Definition includes purposes, design concepts, design criteria, cost and duration estimate and collaborative production with customer and the entire project's stakeholders, on (Ballard and Howell, Lean project management 2003). Lean design phase develops the conceptual design from Project Definition into Product and Process Design. Last Planner

System is applied to the design phase, being a production control tool, with the help of IT tools such as 3D modeling and collaborative design software.

The lean supply phase includes generating detailed engineering of the project design followed by material fabrication and delivery to site. The key benefit of this process is to minimize inventories on site. The whole process should be done to maximize customer value. Once the resources delivered to site, the Lean Assembly phase starts and ends when all the works are handed over to the client. Continuous flow process should be efficiently managed through this phase (G. Ballard, Lean Project Delivery System 2000) .

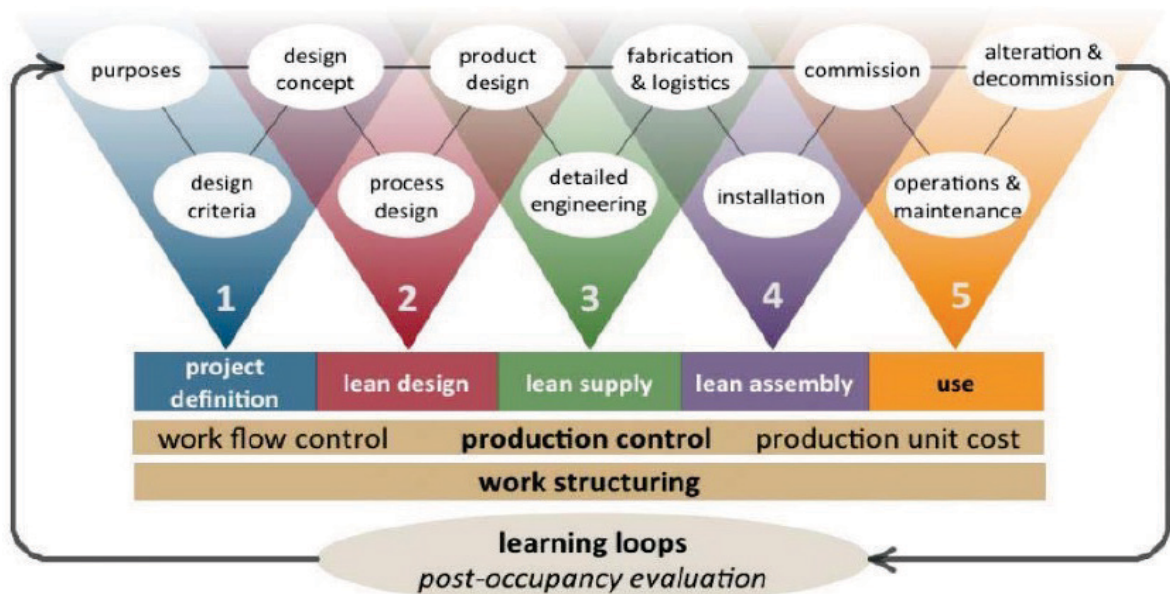


Figure 2. 7 – Lean Project Delivery System (G. Ballard, Lean Project Delivery System 2000)

2.2.3 Lean Construction Principles

According to Howell and Lichting (2008), the aim of approaching projects as production systems is to change the structure of work in both design and construction to maximize project performance (Howell and Lichtig 2008). Lean principles present whole process optimization through collaboration, continuous improvement, elimination of waste and customer satisfaction by delivering the value desired by the end-user (Enache-Pommer, et al. 2010). Lean construction thinking applied to production systems on site has increased awareness of the benefits of stable work, of pull flow of teams and materials to reduce inventories of work in progress (WIP), and of process transparency to all involved (Sacks,

Treckmann and Rozenfeld 2009). Lean construction concentrates efforts on defect prevention (O. Salem, et al. 2006).

Womack and Jones originally outlined the 5 key principles of the Lean methodology as follows (Bertelsen 2002):

1. **Identify Customer Value:** It is essential to meet the required specifications and to deliver the value desired to the end customer. By clearly defining value for product or service, customer value becomes the common focus for parties involved in the project.
2. **Map the Value Stream (operations that generate the value):** The entire process required to deliver a product or service and then assessing to what extent the customer value is being delivered. This represents the end-to-end process that delivers the value to the customer which requires reducing any non-added value activities.
3. **Make the product flow, waiting is waste:** Maintain the work flow by achieving the best sequence of work. The appropriate work flow where the product or service never stops across the entire value chain will simultaneously minimize waste and increase value to the customer.
4. **Use a pull logistic:** It means producing as per the customers need or in-line to the demand of the customer (what the customer wants when the customer wants)
5. **Seek perfection in all operations:** To seek perfection all the time through continuous improvement and implementing appropriate methods to the process.

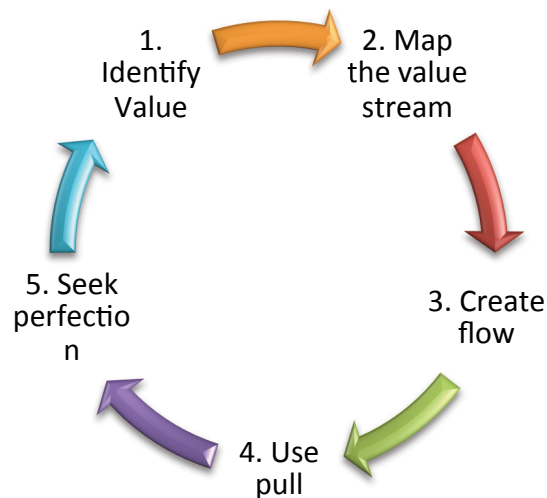


Figure 2. 8 – The 5 Guide Principles of Lean (Bertelsen 2002)

Lean Construction tools and techniques

There are several Lean tools and techniques that can be used to improve performance in the construction industry and to ensure efficient processes in the pre-construction, construction and maintenance phases of a project. Table 2.4 shows a comprehensive list of lean tools and techniques that were addressed in the literature (O. Salem, et al. 2006) (Mostafa E. Shehata 2011). The following is brief description about some of the lean tools and techniques.

1. Flow Process

The lean construction system sees production as a flow of material, information, equipment, and labor from raw material to the product (Yong-Woo Kim and Bae 2010). The stable flow is considered one of the main principles in lean thinking (Sacks, Treckmann and Rozenfeld 2009). Several lean techniques are used to improve flow process and reduce waste. These techniques include but not limited to:

1.1 Reduce Process Variability

Construction projects are subjected to numerous variations during the projects' duration causing uncertainties and instability in the process (Hook and Stehn 2008). In order to avoid variability in process, certain actions should be taken to preclude defects at the source so they do not flow through the process. In lean manufacturing, Fail-safe devices are used to automatically prevent defects from going to the next process (O. Salem, et al. 2006). Yet, in construction this approach was challenging due to the complexity of discovering defects before installation. To ensure quality conformity at the source or defect prevention, Failsafe actions can be implemented on all the activities on site. These actions can be addressed by developing an overall quality assessment and safety action plans at the project start (O. Salem, et al. 2006).

1.2 Reduce cycle time

Reducing variability will result in reducing the work cycle time. The reduction of cycle time in construction is accompanied by reducing the duration of activities and reducing inventory (Sacks, et al. 2010) which requires an effort from the team to redesign the process to make it more flexible and efficient.

1.3 Reduce batch sizes

Reduction the batch sizes improves the work flow. Also, it contributes in reducing the cycle time of the process (Sacks, et al. 2010).

1.4 Increase flexibility

This can be done by quick changeover and by obtaining multi-skilled teams. The reduction of changeover times to move from one activity to the next increases the productivity rates (O'Connor and Swain 2013). Using multi-skilled teams also help in reducing the cycle time and hence, improving the workflow (Sacks, et al. 2010).

2. Pull approach

One of the most significant and important features of lean approach is using the pull scheduling as an appropriate production method. Pull scheduling is considered one of the crucial lean techniques to improve work flow in Construction projects (Thomas, et al. 2003). In a pull system, the flow is a method of controlling product flow in which the quantity of work in progress inventory (WIP) between process stages is minimized, and only products demanded “pulled” by the ultimate “customer” process are produced (Sacks, Treckmann and Rozenfeld 2009).

2.1 Last Planner System (LPS)

It is one of the associated techniques to the pull approach as it supports the predictability and reliability of construction production in which look-ahead scheduling are adopted. The last planner is simply the field supervisor who assigns work to the crew as it allows the conversations between the site management and the trade foreman at proper level of detail preventing critical issues on site to happen. LPS is a collaborative approach to manage project-based production of complex and uncertain projects, allowing problems to be identified and resolved at the source to increase the chance that work flows with no delays (Mossman 2012). The LPS practices in construction include managing tender process, design process, and both design and construction production in the context of integrated project delivery (Mossman 2012). Figure 2.9 shows the Last Planner System procedures. It includes Reverse Phase Scheduling, Six week Look-ahead schedule, weekly work plan and Percentage Plan Completed Charts (PPC). It consists of series of planned conversations as shown in Figure 2. 10.

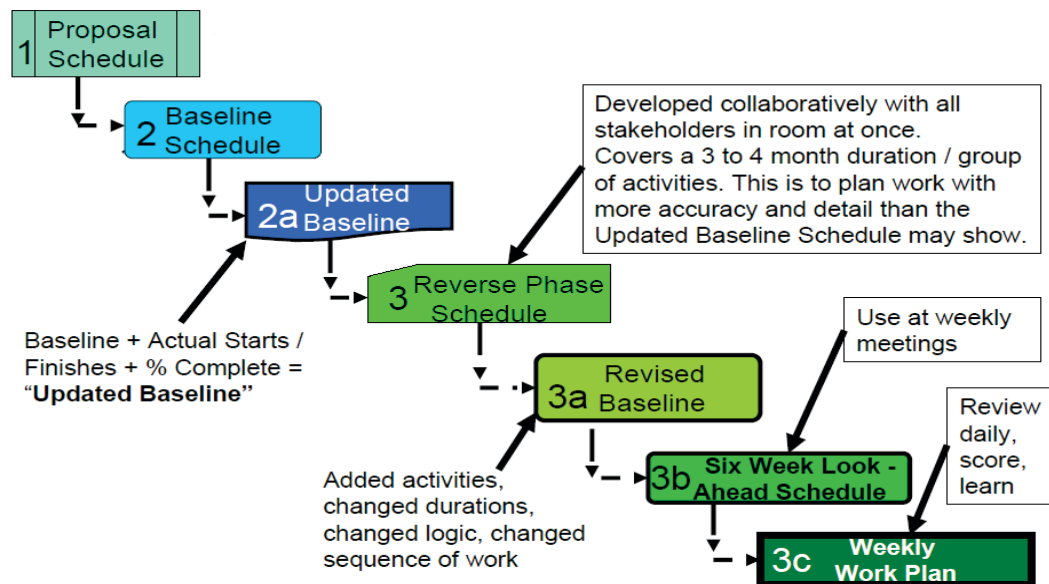


Figure 2. 9 – Last Planner System (Zettel 2008)

Should-Can-Will-Did Planning

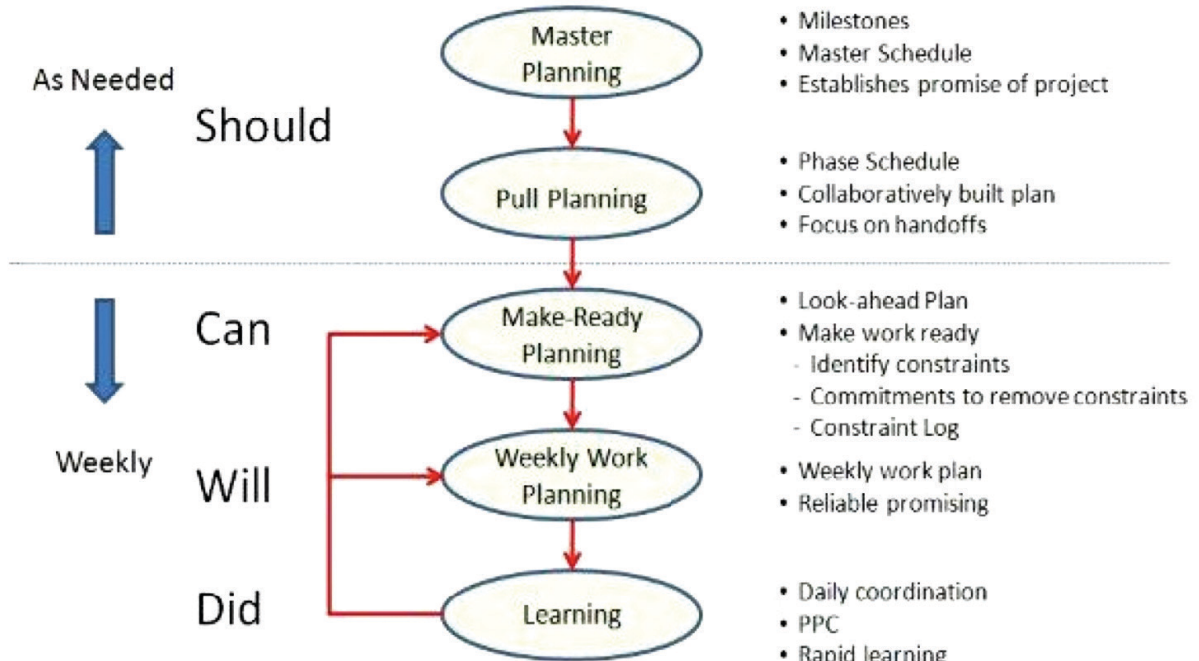


Figure 2. 10 – Last Planner System conversations (Australia 2012)

2.2 Just-in-Time technique

Just in Time means producing only what is needed, when it is needed, and in the amount needed. It is a Pull System that responds to actual customer demand and accordingly leads to reduced inventories (and space), and better equipment productivity (Australia 2012).

2.3 Collaborative Planning

This technique depends on bringing together representatives from all parties involved in a construction project to jointly develop an agreed target programme. It can be usefully used at any point in the life cycle of a project to recover any time or cost overrun that may occur. It comprises five steps:

1. High-level collaborative master target programme
2. Detailed level collaborative master target programme
3. Short-term detailed production plan
4. Daily brief
5. Weekly production control

Integrated Project Delivery (IPD) is one of the methods that can enable the collaboration concept to be implemented efficiently. The American Institute of Architects (AIA) defines integrated project delivery (IPD) as (Dave, et al. 2013):

“a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction”

IPD allows the early involvements for all stakeholders in the project through use of new technologies. One of the fundamental principles of IPD is sharing benefits and risks between all participants. However, all these benefits will be enabled if it is represented by an IPD legal agreement (Dave, et al. 2013).

3. Continuous Improvement

Continuous improvement can help in reducing variability, improving work flow (Sacks, et al. 2010). All the lean techniques are supporting the continuous improvement principle (O. Salem, et al. 2006). Continuous Improvement of the construction process can be classified into two types: Process Improvement and Operation Improvement (O'Connor and Swain 2013).

3.1 Process Improvement

Process improvement means setting an efficient method to deliver a project to improve the overall process in terms of reducing the overall lead time through end-to-end process. The key benefits of implementing this technique are to improve the work productivity, clarify process and roles, minimize waste and reduce lead time (O'Connor and Swain 2013). The main methods related to this technique are: 1) establishing current state map (CSM) to show the current project process including a view of all the delays, disruptions and any other wastes. 2) Establishing future state mapping (FSM) to set a process incorporating all the appropriate Lean techniques so that work flows efficiently (O'Connor and Swain 2013).

3.2 Operation Improvement

It is about improving the work activity method of execution. Operations improvement aims to reduce the cycle time to complete work activity, improve productivity, ensure 'right first time' quality and support safe working by eliminating non-added value activities, monitoring and controlling performance and optimizing resources (O'Connor and Swain 2013). Monitoring and controlling performance through setting measures related to quality, time, cost and safety to control the process (O'Connor and Swain 2013).

4. Transparency

4.1 Five S'

The five S' was initially introduced in manufacturing to identify housekeeping in plants as in lean manufacturing, any resource that does not contribute to better performance is regarded as waste that should be eliminated from the system (O. Salem, et al. 2006). The five S's are sort, straighten, standardize, shine, and sustain. In construction, deploying this tool (5 S's) allow for a transparent job site, at which materials flow competently between warehouses and the pertinent jobs in site. Figure 2.11 shows the storage area after and before applying 5S.



Figure 2. 11 - 5S approach (the left picture store before 5S & the left picture after 5S) (O'Connor and Swain 2013)

4.2 Visual Management

Visualization is important in construction process to avoid any ambiguity in the information. This also helps to identify the work flow and create awareness of action plans on site (O. Salem, et al. 2006). The visualization process can rigorously contribute in supporting the Lean approach in construction if adopted in a fashion appropriate to the context. The technique includes showing the work completion status of the previous activities, the availability of materials, any changes in the layout and the locations of other resources. Pursuing the aforementioned steps can improve the effectiveness of production planning and control and reduce the tendency for errors within the process (Sacks, Treckmann and Rozenfeld 2009). Mobile signs, notice boards, electric wiring, safety signs, project milestones and PPC charts are some of the visualization forms that can be used in construction projects (O. Salem, et al. 2006). Sacks et al. (2009) in their study, provides the ways in which computer-aided visualization can be utilized to support the Lean requirements (Sacks, Treckmann and Rozenfeld 2009). Figure 2.12 and 2.13 shows some visualization tools.





Table 2. 4 - Lean Construction Principles and techniques (O. Salem, et al. 2006) (Refaat H. Abdel-Razek 2007) (Sacks, et al. 2010) (Eriksson 2010)

30 | Page

	Increase flexibility	Reduce changeover times Use multiskilled teams
	Use reliable technology	(e.g. BIM)
Pull	Last planner Collaborative Planning Just-in-Time	Pull scheduling approach Reduce inventory
Continuous improvement	Huddle meetings First-run studies Current State Mapping Future State Mapping	Start of the day meeting Plan Do Check Act
Transparency	Five S's Visual Management	Visualize production methods Visualize production process

2.2.4 Application of Lean in Construction Industry

The lean thinking has recently penetrated the construction industry to reform the traditional construction management approach. Lean thinking was implemented and examined in several construction sectors such as infrastructure, supply chain, finishes, and concrete and office related activities. The following summarizes some of the various application of lean in different trades in construction. A review on lean effect and benefits in construction is summarized in table no.

- **Construction supply chain**

Being complex, a study was conducted to show the potential improvements in applying lean concepts to construction supply chains by presenting the case of pipe supports used in power plants. It was concluded that value stream analysis, one of the lean concepts, is a reliable tool to improve supply chain performance as it helped in identifying wastes in the process. Also, several lean principles were used to improve the performance such as reducing batch size, early involvement of suppliers in design stage, standardization of process, and improve supplier selection (Tommelein 2002).

Another study was conducted in Brazil to examine the application of value stream mapping (VSM) tool on the aluminum supply chain from raw materials to the job site installation. It was concluded that VSM shows a high potential to help the application of lean concept beyond job site (Fontanini and Picche 2004).

- **On-Site Subcontractor Evaluation**

Subcontractor evaluation can play a key role in improving their productivity during a construction project. A study was conducted in Chile to develop on-site evaluation method for subcontractors based on lean principles and partnering practices. This method was achieved through periodic evaluations and visualization tools to improve the communication between the subcontractors and main contractors. This method helped in resolving many disputes, and helped the subcontractors' supervisors to monitor their workers on-site performance. It also helped the main contractor to select the suitable subcontractor based on their previous performance in future works. This supports the idea of collaborative relationship with the subcontractors that consistently perform well (Maturana, et al. 2007).

- **Finishing Trades in buildings**

The efficiency of work flow of interior finishing trade teams for building projects is a complex task due to the unavailability of design information at certain stages of construction. The challenge is to efficiently allocate the teams in the available work zones to prevent accumulation of WIP. In an attempt to solve this problem, lean concepts were implemented through visualizing the process on site. This was done through using status board generator software using small icons drawing in each cell that indicate the work status and the future work as well. Using this status board has helped the trade supervisor to efficiently allocate his team by viewing the near future work, work should not be done and the rework required. Also, the status board helps in data collection for progress monitoring, making project status information available to all levels of management. Consequently, novel-computer aided visualization tools showed its ability in improving the work flow by revealing the rate of progress and the bottlenecks of the process (Sacks, Treckmann and Rozenfeld 2009).

- **Construction Submittals**

Any delay in construction submittals can negatively impact the project schedule. Therefore, improving the office activities is crucial in any construction project for a better work flow on site. By applying lean concepts in an office process as the submittals process in some construction firms in San Diego, considerable improvements have been noticed. These improvements include time reduction by eliminating wastes and reducing non-value adding activities (Garrett and Lee 2011).

- **Improving labor work flow in construction**

Several studies have examined the impact of reliable work flows as a lean principle on labor work flow. Thomas et al. (2003) highlighted the importance of the Labor flow for improving the workflow management in the construction process by using data from three projects involved construction of 3 bridges covering 137 workdays. The Flexible Capacity approach was addressed as a potential area for improving construction performance. They concluded that ineffective labor flow lead to ineffective flow management, hence, lean improvement initiatives should focus more on workforce management strategies for better labor performance (Thomas, et al. 2003).

In another study, Thomas et al. 2002 examined the issue of variability in construction and its impact on project performance using data from 14 concrete formwork projects. They reached a conclusion that reducing the variability in labor productivity is more intensely correlated to better performance than reducing workflow variability (H. Randolph Thomas, et al. 2002).

- **Formwork Engineering**

A study was conducted in Taiwan using lean concepts to improve traditional formwork engineering. The improvements include reductions in resource waste and increases in operational value by using value stream mapping to identify the process waste. The results of this study showed that applying lean concepts can reduce wastes resulted from walking and searching in mold assembly and machining (Ko, Wang and Kuo 2011).

- **Construction projects (Structure and Finishes)**

A study was done in Nigeria to evaluate the effectiveness of implementing some Lean Construction Techniques in construction of 80 housing units. These techniques include Last Planner, Daily Huddle Meetings, and Increase Visualization. The results showed improvements in time management that lead to a lot of savings in the project cost. The project was completed in 62 days using lean techniques instead of 90 days (Samalia Adamu 2012).

Another study took place to show how VSM can improve the performance of civil engineering projects by allowing the site management to visualize the flows of materials, resources and information. This was examined through the fixing of reinforcement in two

bridge construction projects. The results showed improvements in lead time, inventory level and cost by approximately 80% (Simonsson, et al. 2012).

In a study conducted by Salem, et al. (2006), a Lean Assessment tool was utilized to assess the implementation of several Lean Construction techniques. The assessment tool evaluates six lean construction elements: last planner, increased visualization, huddle meetings, first-run studies, five S's, and fail safe for quality (2006). In the test study, the selected General Contractor agreed to implement and test 6 lean construction techniques on a parking garage project. The results of the study were tangible in that the project was under budget and 3 weeks ahead of schedule. (O. Salem, et al. 2006)

- **Precast concrete fabrication**

A study was conducted to describe the application of lean production concepts and techniques to structural precast concrete fabrication. Last Planner and Five S techniques were used to improve the performance. The results achieved included shop cycle time and lead time reduction, increased throughput rate, and improved productivity (Glenn Ballard 2003).

- **Infrastructure projects**

The successful use of Lean techniques in the infrastructure industry was shown in a study conducted on tunneling project. The lean techniques used in this study include standardization, mapping, fishbone diagrams, and 5S approach. As a result, the productivity has increased by 43% and the project was on schedule and no delays were incurred. Additionally, the project profit was doubled (Wodalski, et al. 2011).

2.2.5 Assessing and Evaluating Lean techniques

Vieira et al. used in their study the Rapid Lean Construction-Quality Rating Model to evaluate the application of Lean Construction principles of two construction companies in the State of Goiás (Vieira, Souza and Amaral 2012). The performance level of these companies was obtained in respect of applying and understanding lean principles & thinking. After the evaluation was done, recommendations and suggestions were

introduced to help the companies implement lean thinking in a more efficient way (Vieira, Souza and Amaral 2012).

To ensure that the expected benefits of applying lean thinking to construction projects are actually being delivered, evidence should be provided to the concerned stakeholders to encourage them continue applying this new approach. Lean benefit realization management (LBRM) is a “systematic way of ensuring that the outcomes of a Lean improvement programme deliver benefits that are advantageous to stakeholders”. This system presents some tools and techniques that help in quantifying lean benefits (Smith 2013).

Chapter Three

3. Questionnaire

For the purpose of achieving the goal of this research, a questionnaire was designed and administrated in one of the leading construction companies in Egypt. This questionnaire was used to investigate the main factors impacting the construction projects performance and the employees ‘understanding regarding the lean thinking/techniques in the Egyptian construction industry. Based on this questionnaire and the literature survey, the problem statement was better formulated.

Sample Selection

The questionnaires have been distributed among construction engineers within the same organization. This organization is one of the leading construction companies in Egypt. It has a market capitalization of \$8,964 million (Hussein 2012). In addition, it is considered the second leading company in construction industry in Egypt. Globally, it ranks among the world’s top 250 global contractors. Its ranking in 2013 was 182 in comparison with the 1st leading Egyptian construction company which ranked no. 106 among the 250 companies. However and for the sake of this research, the 2nd leading company was chosen as it provides international engineering and construction services primarily on infrastructure, industrial and high-end commercial projects in Europe, the Middle East and North Africa

for public and private clients (http://www.contrack.com/?page_id=1784 n.d.). Being an international company, it has a firm management system that regularly measures the performance, and processes efficiency, to practice continuous improvement. These attributes relate to an extent to the lean thinking approach. Therefore, the questionnaire was conducted in this organization to see the impact of using some of the techniques that relate to lean thinking on the projects' performance.

Sample size

The sample size (N) was 25 as it was only focused in the building projects inside the company. Twenty Five questionnaire forms have been distributed among different engineers in different projects within the same organization. Only 20 out of 25 responded to the questionnaire.

The sample size was determined and taken from one company which is the largest listed construction company in Egypt (<http://www.nbkcapital.com/> 2010). The reason behind selecting this company is their tendency to enhance the quality of work by setting group of policies that should be followed by all the employees to ensure that the company operates in a way that meets or exceeds the requirements of their customers. However, this limitation in sample size impacted the results of the questionnaire. It provided optimistic values about the respondents' awareness and appreciation of lean construction due to the company's firm management system that supports in a certain way the lean thinking. The results would have significantly differ if the questionnaire was distributed among all the construction firms in Egypt due to the absence of the lean thinking in most of them. New management systems such as lean should be first examined at large scale companies. This allows the systems to be established in more professional environment with a lot of potentials and hence can be easily applied to smaller scale companies.

Structure of the Questionnaire

The key purpose of this survey is to identify the employees' understanding regarding the lean thinking/techniques in the Egyptian construction industry. The questionnaire is classified into 3 main sections as follows:

- Section (A): is structured to investigate general information and background about the respondents' experience.
- Section (B): is structured to identify the factors affecting the overall performance of the project in current practice and the methods adopted to reduce these negative impacts.

- Section (C): is structured to examine the respondents' awareness about lean techniques and their applications in the Egyptian construction industry.

This questionnaire and all of its three sections are included under Appendix A of this thesis.

Section A: Project Information

This section is structured to investigate general information about the project and background about the respondents' experience. The experience of the respondents varied between 5 years' experience and above 20 as illustrated in fig.3.1 and 90 % of them have a position of project managers as shown in fig.3.3. All the projects were new buildings. Most of the

EGP in projects values fall between 100 to 500 Million as illustrated in fig.3.2.

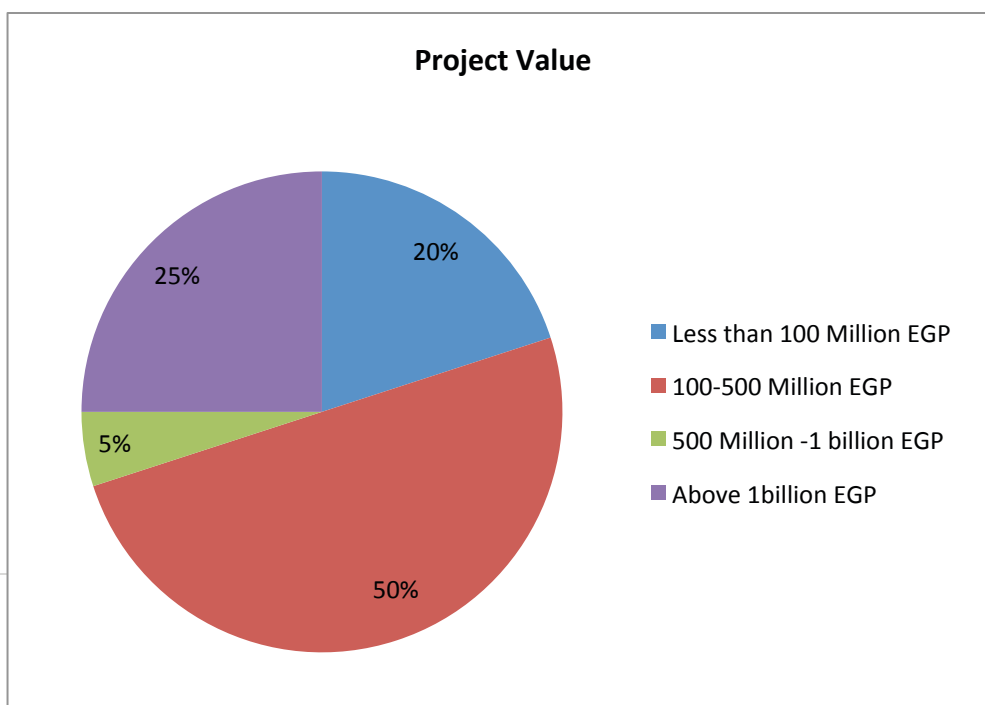
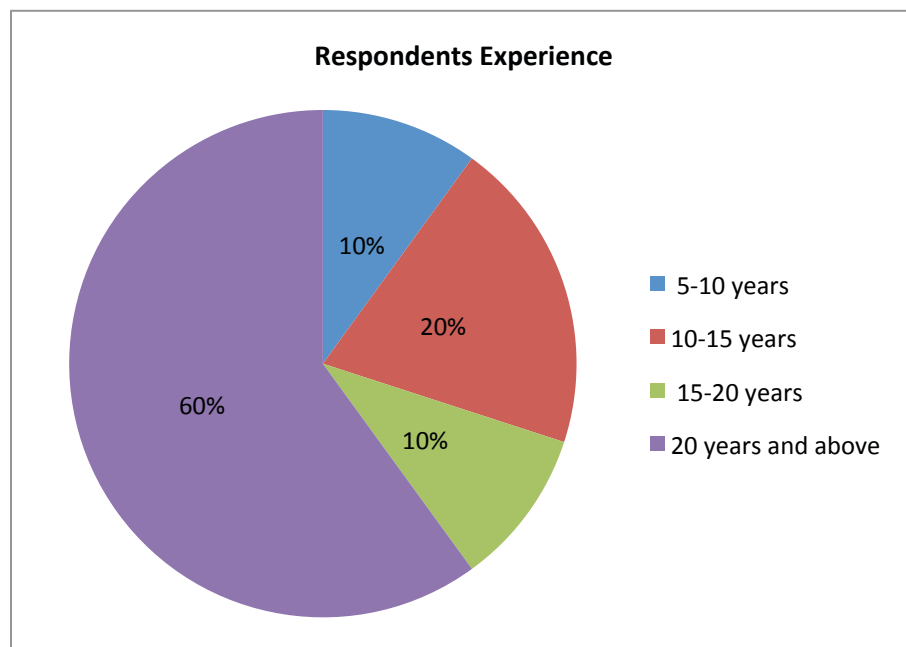


Figure 3.1 - Experience of the Respondents

Figure 3. 2 - Project Values

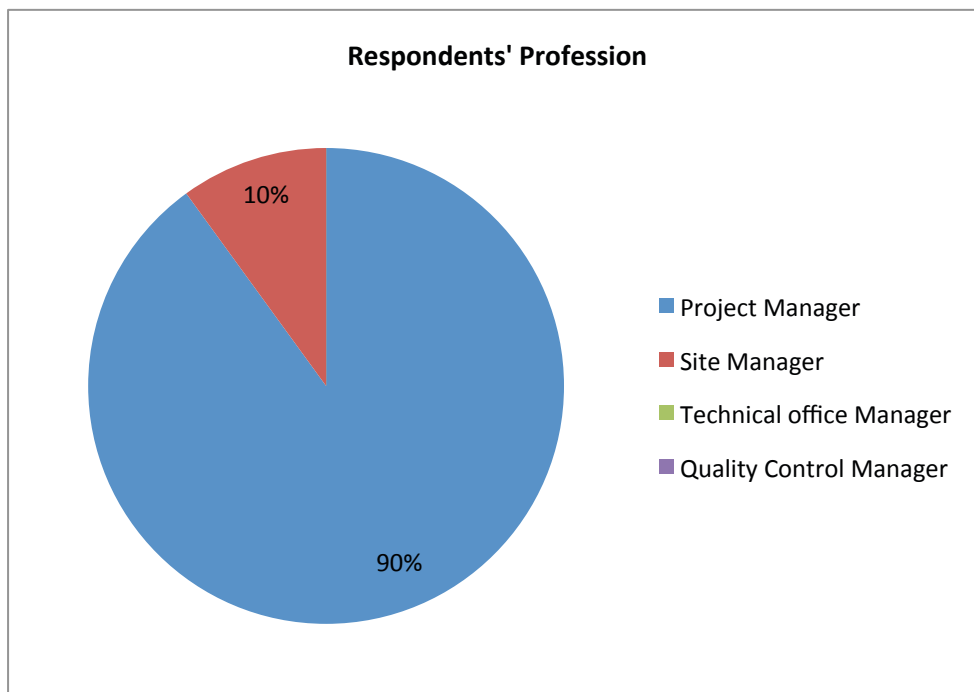


Figure 3. 3 - Respondents' professions

Section B: Factors affecting project performance in construction projects in Egypt

The purpose of section (B) is to identify the factors affecting the overall performance of the project in current practice. The impact of several factors on the project performance was measured. These types of question give an indication of the major problems that encounter the project manager in the operation phase. These factors cause a lot of disruptions to the construction process. Table 3.1 shows the frequency of the factors impacting the overall project performance.

Table 3. 1 – The frequency of factors impacting the project performance in Egypt

		Frequency of its impact on Cost, Time, Quality & productivity			
	Factors Impacting the project Performance	Cost	Time	Quality	Productivity
1	Change orders by owner during construction (Variations)	100%	100%	55%	90%
2	Rework due to errors during construction	70%	75%	40%	70%
3	Poor site management and supervision by contractor	55%	60%	45%	55%
		Frequency of its impact on Cost, Time, Quality & productivity			
	Factors Impacting the project Performance	Cost	Time	Quality	Productivity
4	Difficulties in financing project by contractor	50%	45%	30%	40%
5	Poor communication and coordination by contractor with other parties	55%	65%	45%	50%
6	Ineffective planning and scheduling of project by contractor	45%	50%	20%	45%
7	Improper construction methods implemented by contractor	65%	60%	65%	60%
8	Poor qualification of the contractor's technical staff	80%	85%	80%	80%
9	Mistakes and discrepancies in design documents	90%	100%	75%	95%
10	Un-use of advanced engineering design software and tools	45%	50%	35%	40%

11	Inadequate details in drawings	65%	80%	65%	60%
12	Complexity of project design	60%	60%	30%	45%
13	Insufficient data collection and survey before design	40%	30%	25%	35%
14	Delay in material delivery	80%	90%	30%	60%
15	Changes in material types and specifications during construction	85%	75%	45%	75%
16	Damage of sorted material while they are needed urgently	55%	55%	25%	20%
17	Low productivity and efficiency of equipment	60%	55%	15%	55%
18	Unqualified workforce	55%	50%	45%	55%
19	Low productivity of labors	85%	85%	50%	85%
20	Site uncertainties	65%	65%	35%	60%

Respondents were asked to rank the factors, using a Likert scale (1-5), as either 'Very High (5)', 'High (4)', 'Average (3)', 'Low (2)', or 'Very Low (1)'. The following describes the major factors impacted the Cost, Time, quality, and productivity as per the rankings done by the respondents. The major factors impacting the project performance are identified based on the following:

1. Factors that its frequency of occurrence more than 50 % (10 out of 20),
2. Factors with total impacts of average level, high level and very high levels greater than or equal 50% of the total respondents of each factor

▪ **Main Factors Impacting project cost**

As shown in Figure 3. 4, the major factors that impact the project cost as per the aforementioned criteria are (17 factors out of 20 factors):

- change orders by Engineer/owner,
- Rework due to errors, Improper construction methods,
- Poor site management and supervision by contractor
- Difficulties in financing project by contractor
- Poor communication and coordination by contractor with other parties,
- Improper construction methods implemented by contractor
- poor qualification of the contractor's staff,

- Mistakes and discrepancies in design documents
- Inadequate details in drawings,
- Complexity of project design,
- Delay in material delivery
- Changes in material types and specifications during construction
- Damage of sorted material,
- Low productivity and efficiency of equipment
- Unqualified workforce
- Low productivity of labors
- Site uncertainties

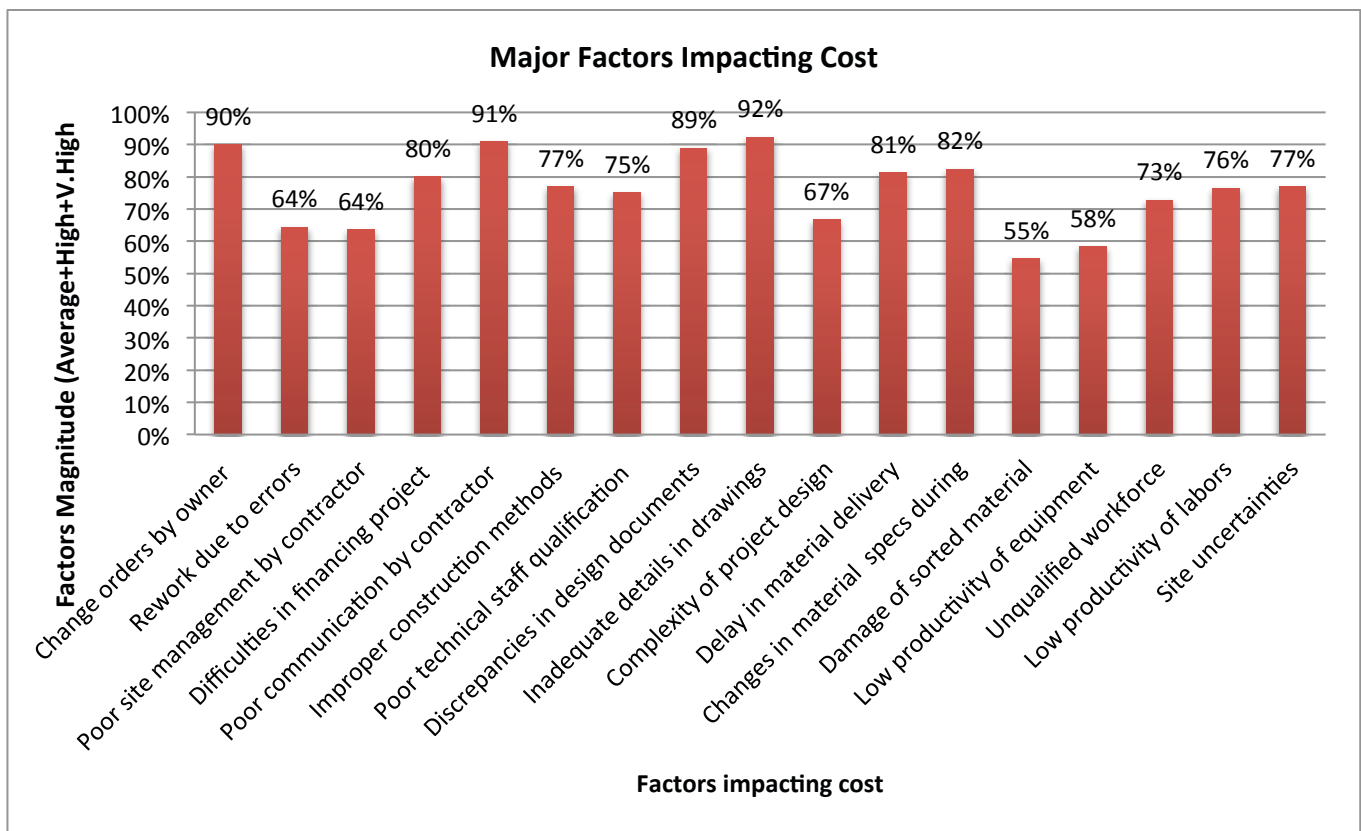


Figure 3. 4 - Factors impacting the project cost

▪ **Main Factors Impacting project time**

As shown in Figure 3. 5, the major factors impacting the project time as per the aforementioned criteria are (17 factors out of 20 factors):

- Change orders by owner

- Rework due to errors during construction,
- Poor site management and supervision by contractor
- Poor communication and coordination by contractor with other parties,
- Ineffective planning and scheduling of project by contractor
- Improper construction methods implemented by contractor
- Poor qualification of the contractor's technical staff,
- Mistakes and discrepancies in design documents,
- Un-use of advanced engineering design software and tools,
- Inadequate details in drawings,
- Complexity of project design,
- Delay in material delivery
- Changes in material types and specifications during construction
- Damage of sorted material while they are needed urgently,
- Unqualified workforce
- Low productivity of labors
- Site uncertainties

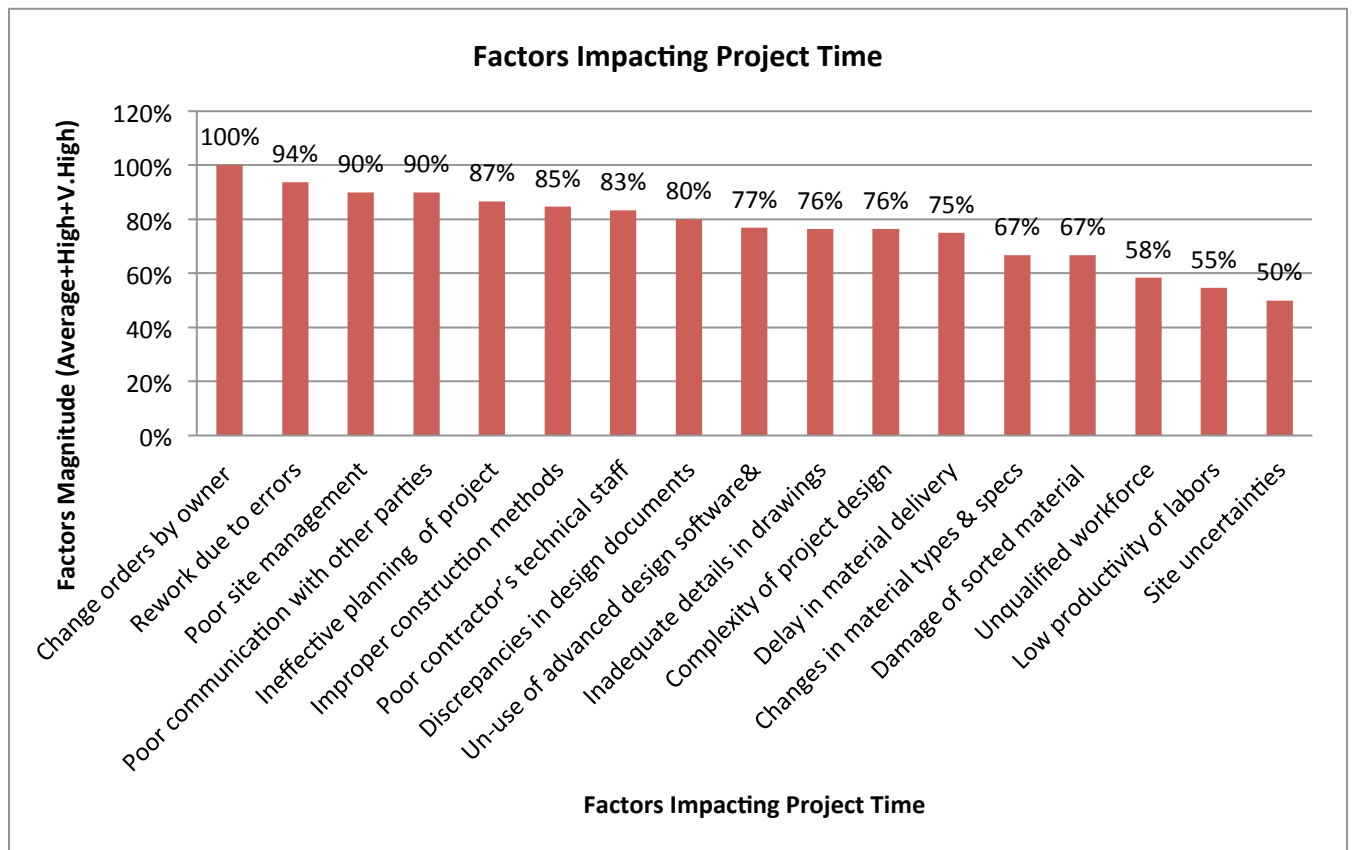


Figure 3. 5 - Factors Impacting Project Time

▪ **Main Factors Impacting project quality**

As shown in Figure 3. 6, the major factors impacting the project quality as per the aforementioned criteria are (5 factors out of 20 factors):

- Improper construction methods implemented by contractor
- Poor qualification of the contractor's technical staff
- Mistakes and discrepancies in design documents
- Inadequate details in drawings
- Low Productivity of labors

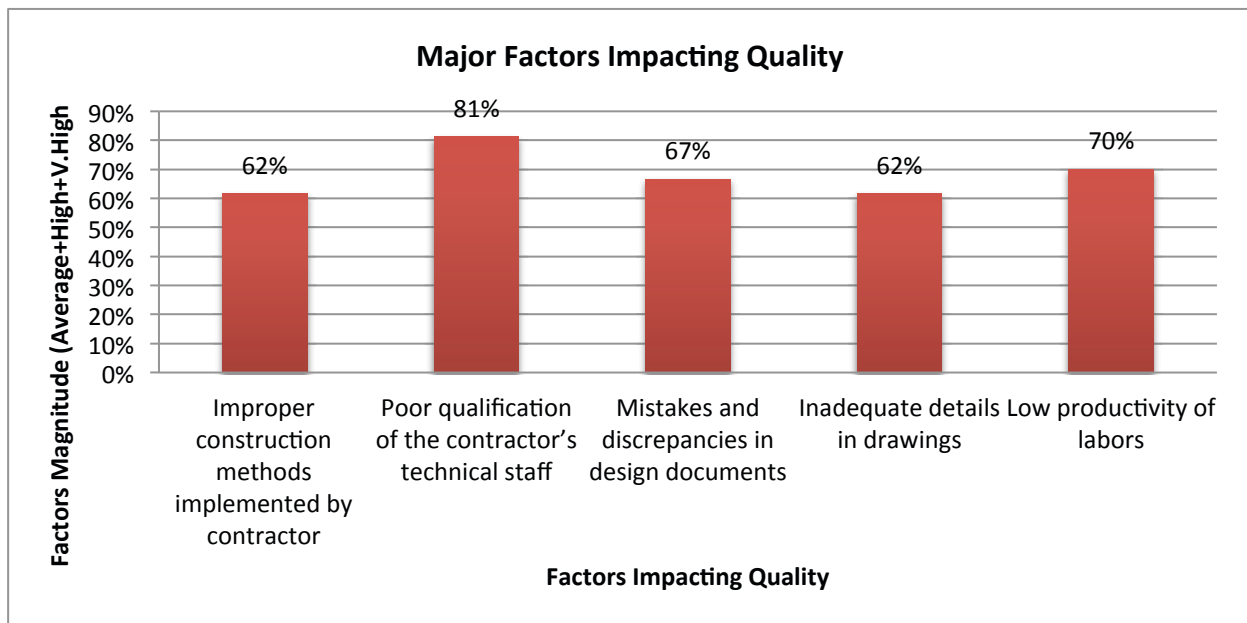


Figure 3. 6 - Factors impacting project quality

Main Factors Impacting project productivity

As shown in Figure 3. 7, the main factors impacting the project the major factors impacting the project productivity as per the aforementioned criteria are (14 factors out of 20 factors):

- Change orders by owner during construction,
- Rework due to errors during construction
- Poor site management and supervision by contractor

- Poor communication and coordination by contractor with other parties,
- Improper construction methods implemented by contractor
- Poor qualification of the contractor's technical staff
- Mistakes and discrepancies in design documents
- Inadequate details in drawings,
- Delay in material delivery
- Changes in material types and specifications during construction
- Low productivity and efficiency of equipment
- Unqualified workforce
- Low productivity of labors
- Site uncertainties

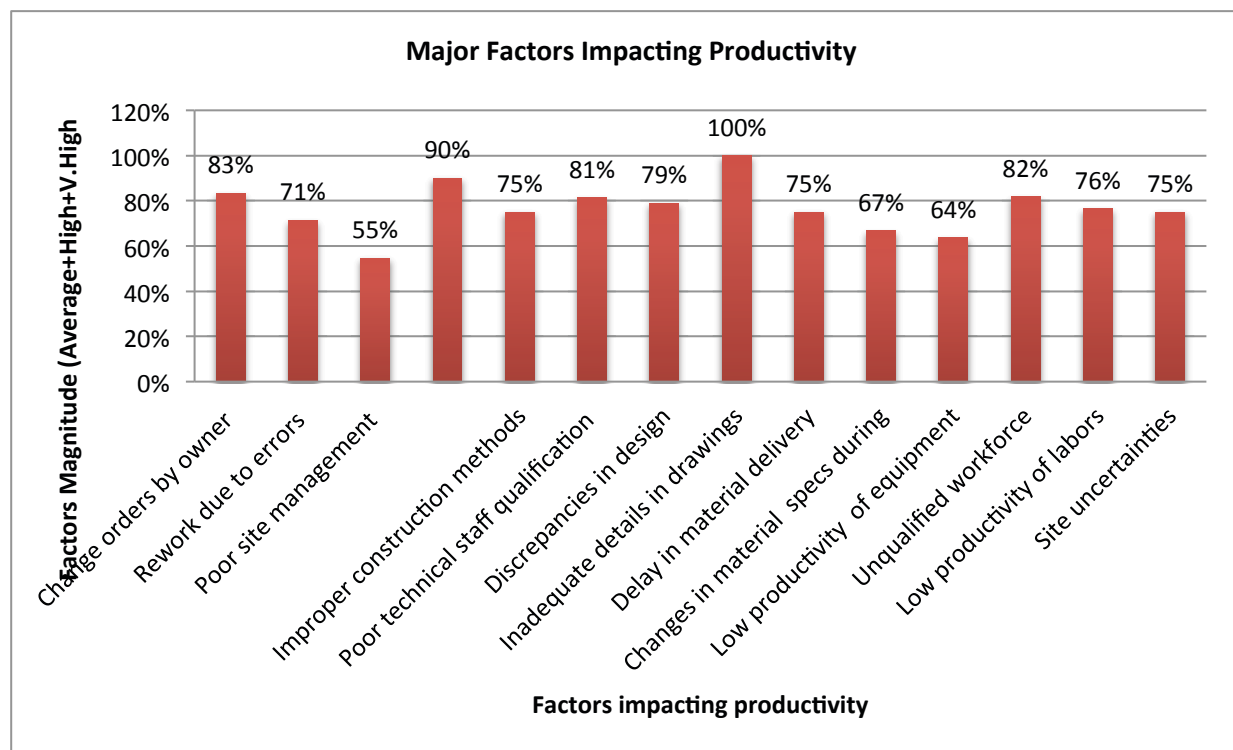


Figure 3. 7 - Factors impacting project productivity

Section C: Respondents' awareness about lean techniques and their applications in the Egyptian construction industry

Section (C) is structured to examine the respondents' awareness about lean techniques and their applications in the Egyptian construction industry. The questionnaire used a

Likert-type scale from 1 (very low) to 5 (very high). The first two questions examined the potential of using new management techniques in construction as well as respondents' awareness about lean techniques as illustrated in Figure3. 8 and Figure 3. 12 respectively. The results showed that 55% of the respondents have high potentials to use new management techniques/approached in construction field in Egypt. Regarding the respondents awareness about lean construction, 55% of them are almost not aware of this approach while 40% of the respondents were moderately aware.

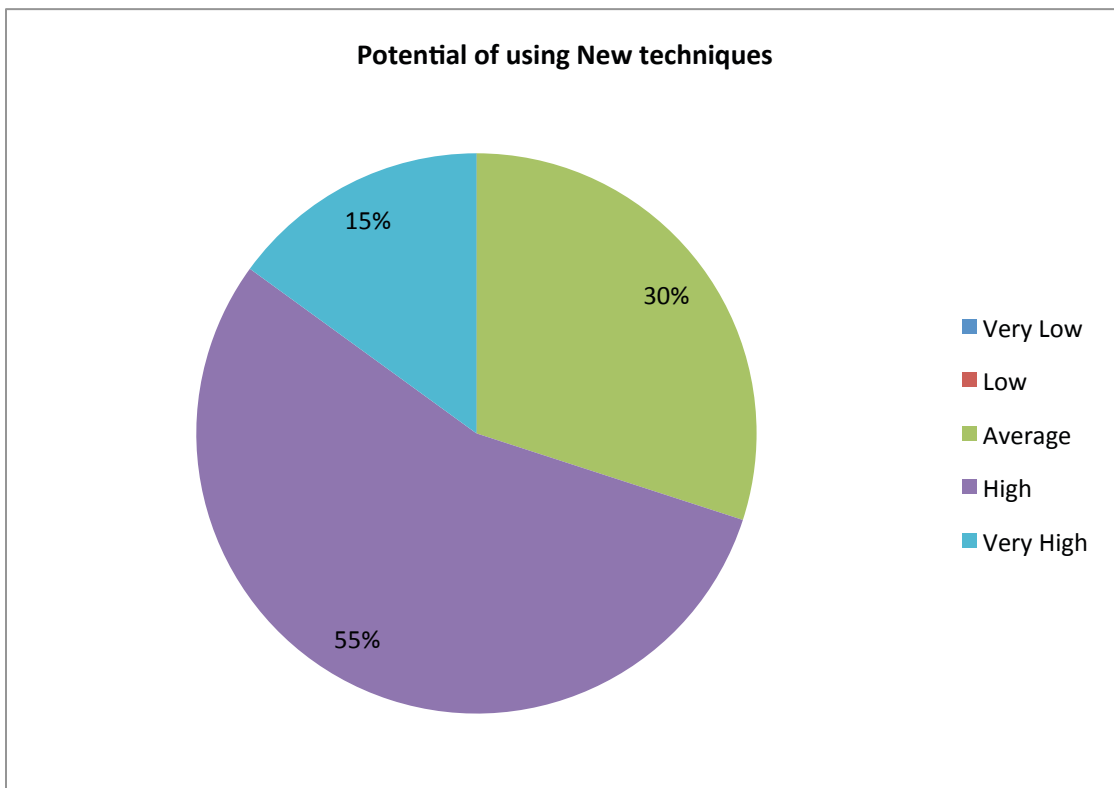


Figure3. 8- Potential of using new management techniques in construction

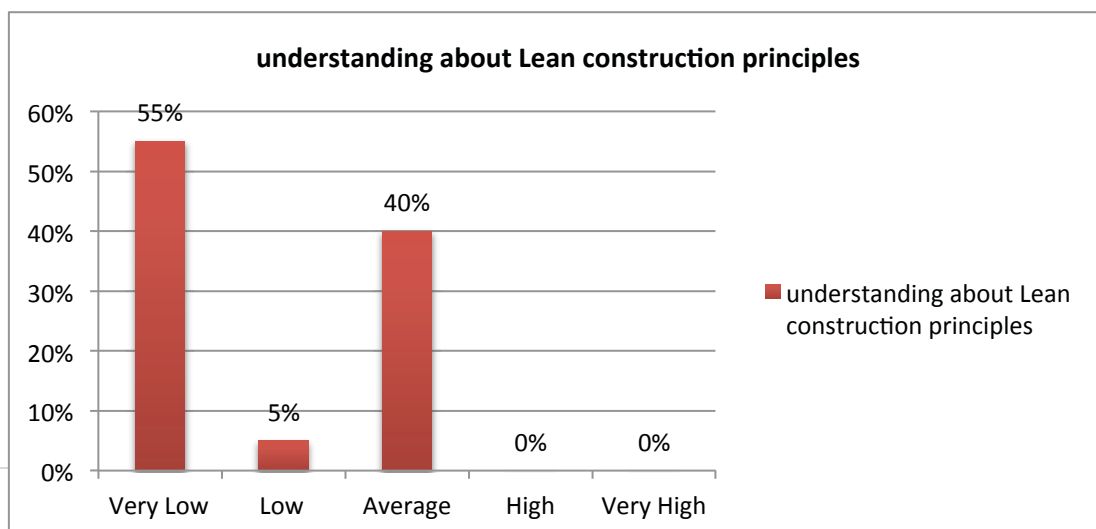


Figure3. 9 - Respondents' awareness about lean techniques

Question number 3, 4, and 5 were related to the computer-aided tools that can effectively help in improving the overall project performance. Only 14 out of 20 respondents are using believes that the computer-aided tools are improving the project performance. The questionnaire showed that only 30% of the respondents in their projects use BIM as an innovative tool to improve the performance while the remaining 40% out of the 70% who are using computer-aided tools use 3D-modelling to enhance performance. Figure 3.10 shows percentage of respondents who use computer-aided tools to improve work performance and figure 3.11 shows the computer-aided tool used in their projects.

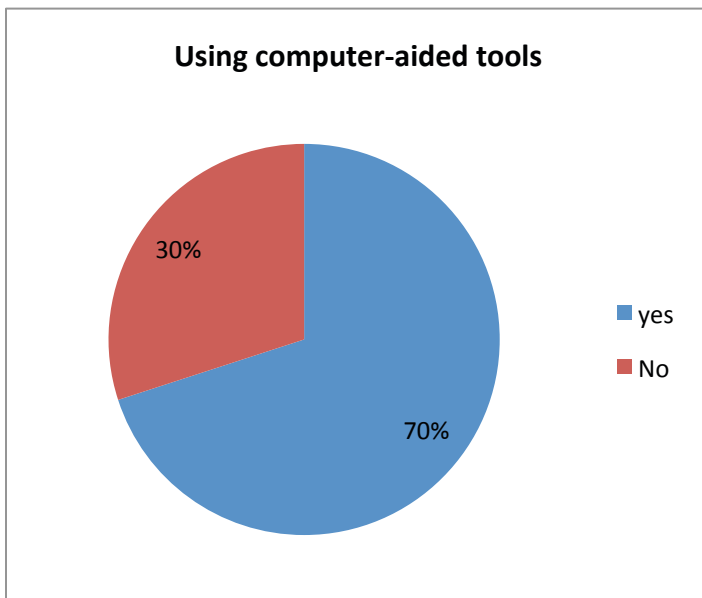


Figure3. 10 - Percentage of respondents using computer-aided tools

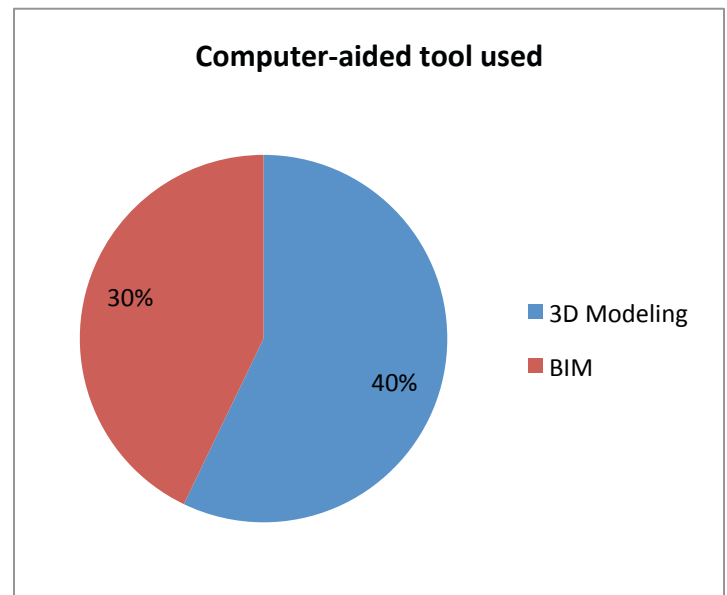


Figure3. 11- Computer aided tool used

In Question number six the different principles of lean were examined to see the possibility of applying lean approach to construction projects in Egypt. The following principles were evaluated using Likert-type scale from 1 (very low) to 5 (very high). Then the mean score of each principle was calculated as the average of the 5 points of the rating scale of the total respondents (From Very low to very high)

Waste Reduction

Fig. 3.12 shows the rating of each principle related to waste reduction in Egyptian construction projects. It can be concluded that more effort should be done to increase the awareness of employees on site about waste reduction as 55% of the respondents believe that the people awareness about waste reduction is either low or very low. Also, more focus should be given to decrease the material waste on site as 70% of the respondents

believe it is either average or very high. The concern to reduce the non-added value activities should be improved. Also, the quantification of the material loss and productivity loss should be highly considered. Fig.3.13 shows mean scores for each principle for the 20 respondents.

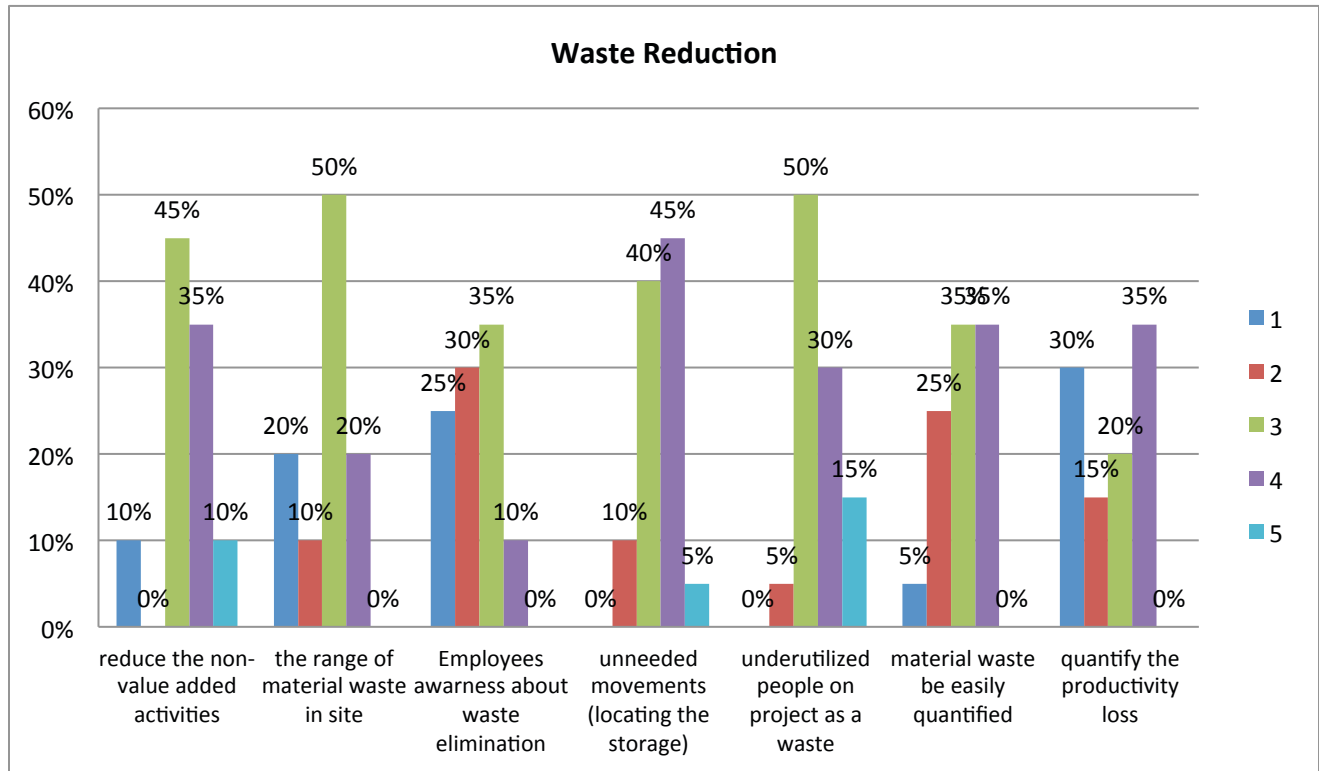


Figure 3. 12 – Waste Reduction

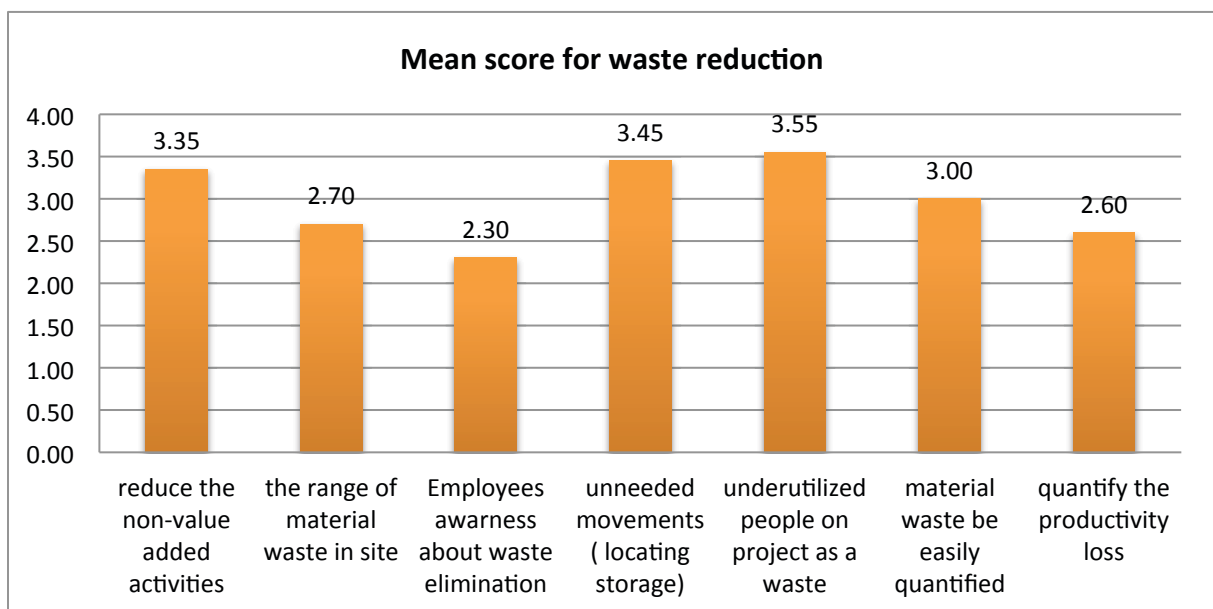


Figure3. 13 - Mean Scores for waste reduction

Reduce Variability

Fig. 3.14 shows the rating of each principle related to reduction of variability. It was concluded that much concern was given to process standardization within the projects in the same organization which reflects their potential for adopting some of the lean construction techniques. Fig.3.15 shows mean scores for each principle for the 20 respondents.

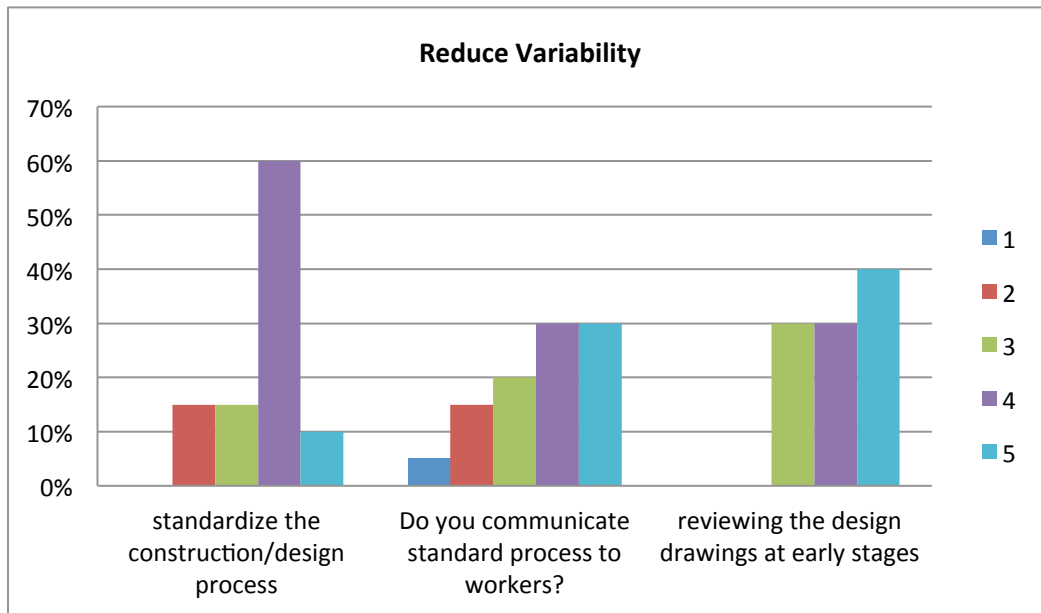


Figure3. 14 – Reduce Variability

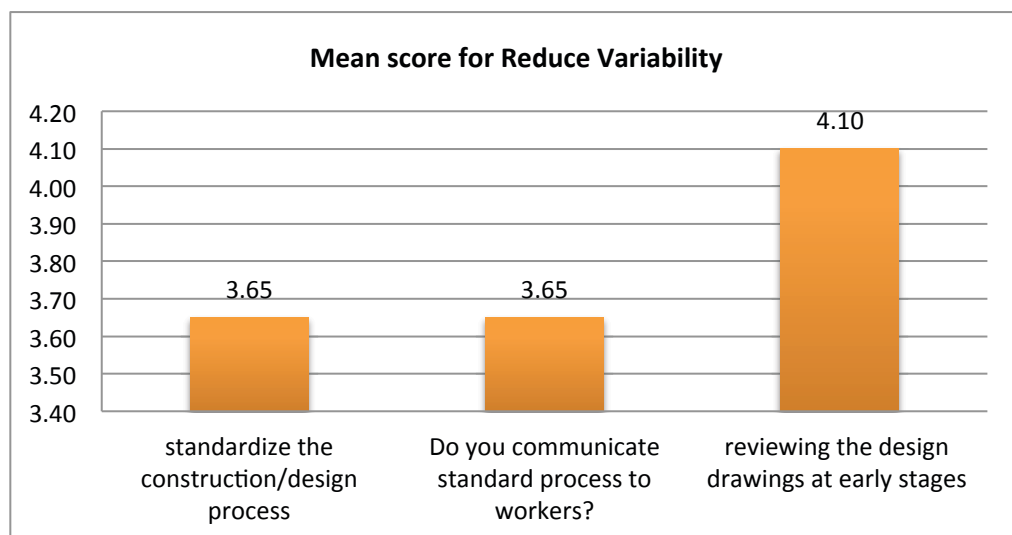


Figure 3. 15 – Mean score for Reduce Variability

Increase Transparency

Fig. 3.16 shows the rating of each principle related to transparency on site in construction projects in Egypt. It can be concluded that only few projects are using visual management to improve the performance and that most of the visualization tools used are related to safety signs only as more than 50% of the respondents are not deploying visual management in their projects. Hence, more attention should be given to increase the process visualization on site. Conversely, the housekeeping of site is highly adopted in most of the projects. Fig. 3.17 shows mean scores for each principle for the 20 respondents.

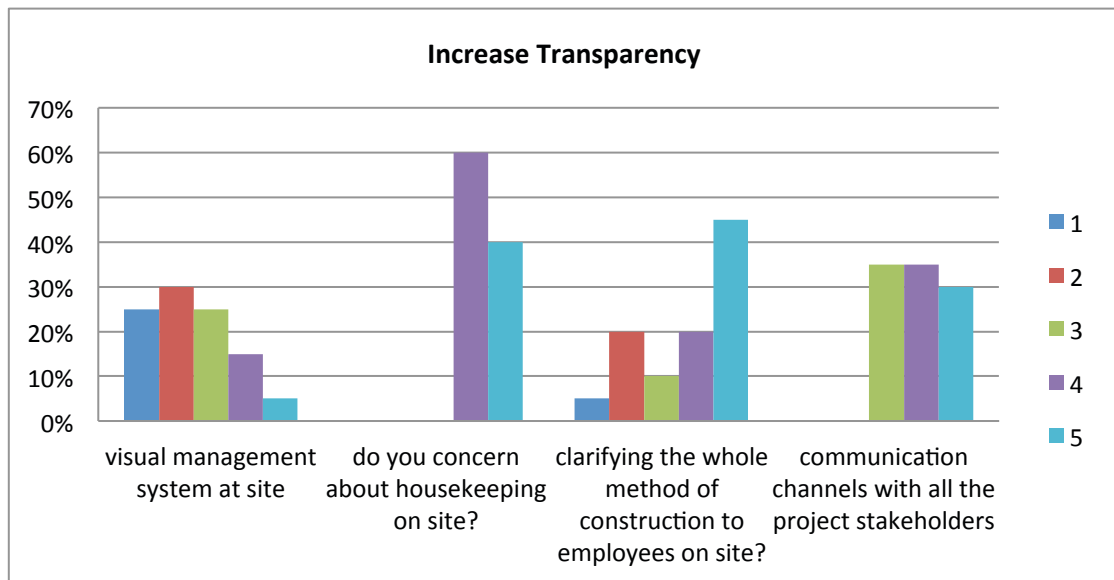


Figure3. 16 – Increase Transparency

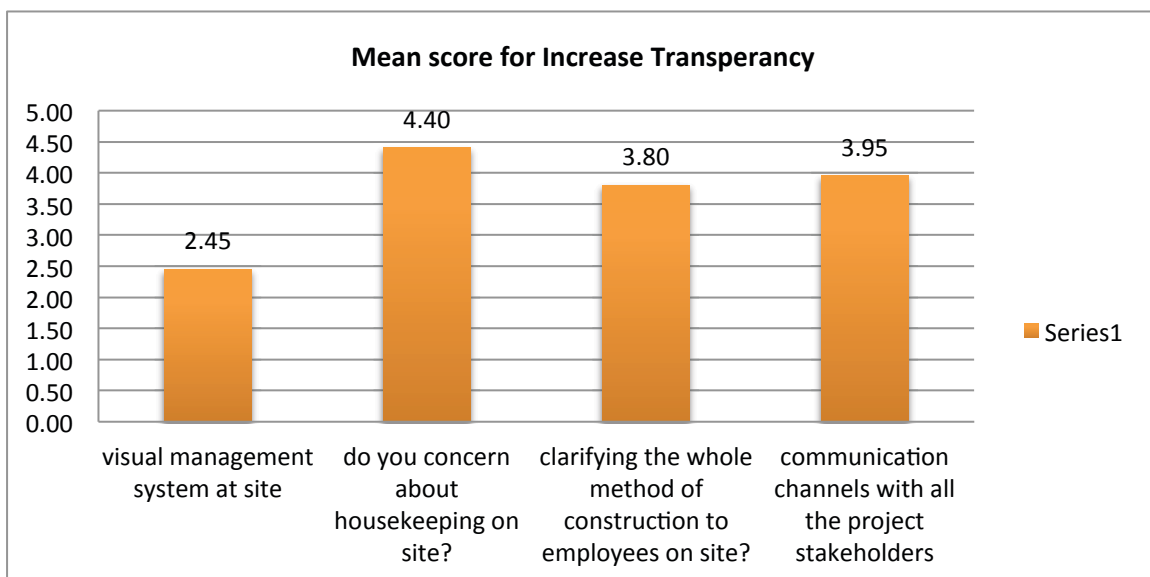


Figure 3. 17 – Mean score for Increase Transparency

Flow Variability

Fig. 3.18 shows the rating of each principle related to flow variability on site in construction projects in Egypt. It can be concluded that the just-in-time method are barely used on construction project in Egypt as well as the concept of work flexibility (using multi-skilled labor) and visualization management as more than 50% of the respondents are almost not using these techniques. The concept of collaboration with the suppliers needs improvement to be more efficient as 30% of the respondents have low concern about collaboration. On the contrary, there is decent potential for using the schedule look-ahead to improve the process work flow. Fig. 3.19 shows mean scores for each principle for the 20 respondents.

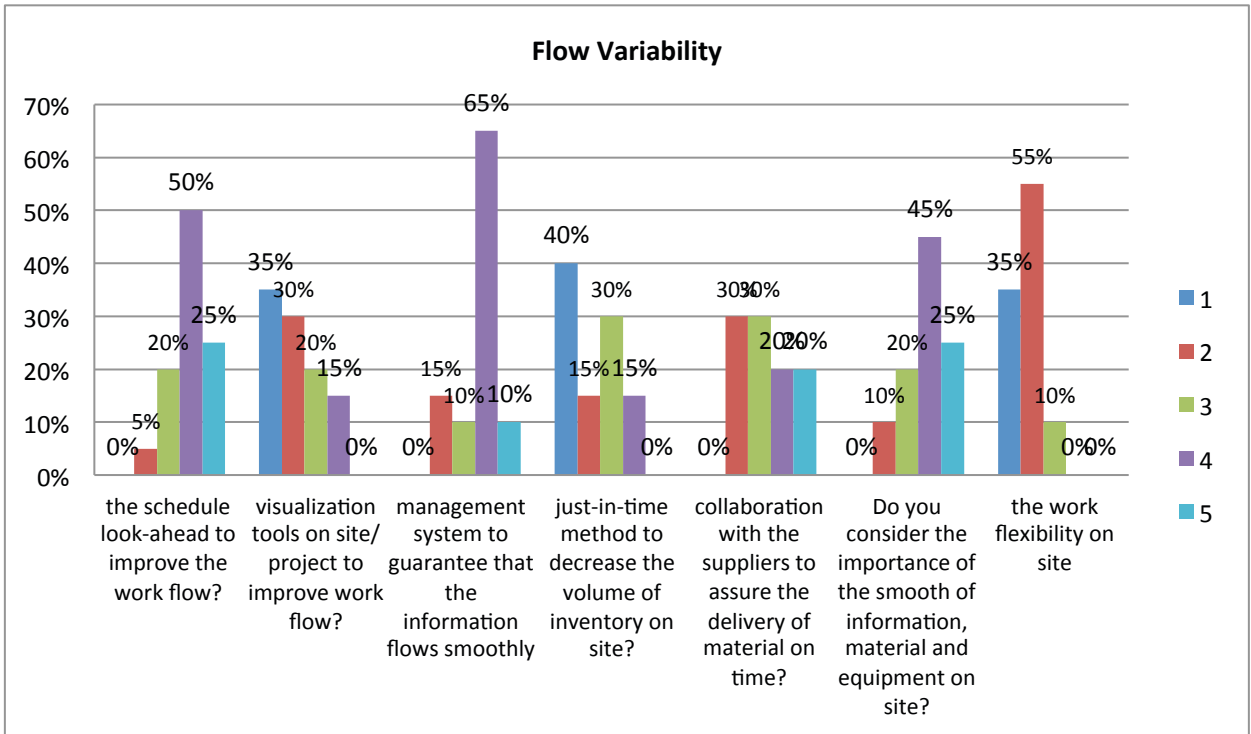


Figure 3. 18 – Flow Variability

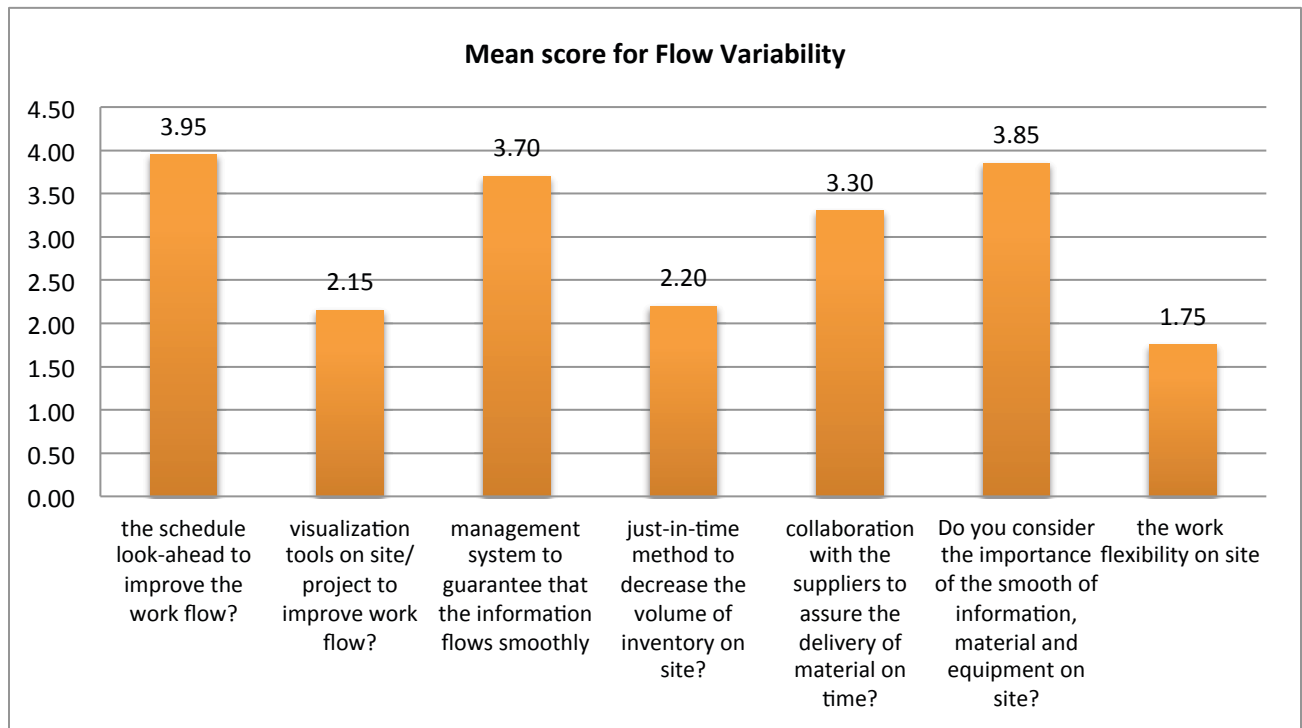


Figure3. 19 – Mean score for Flow Variability

Continuous Improvement

Fig. 3.20 shows the rating of each principle related to continuous improvement on site in construction projects in Egypt. It can be concluded that there is noticeable potential for adopting most of the techniques related to the continuous improvement. Only the two techniques related to prefabrication and benchmarking need some attention and improvement. Fig. 3.21 shows mean scores for each principle for the 20 respondents.

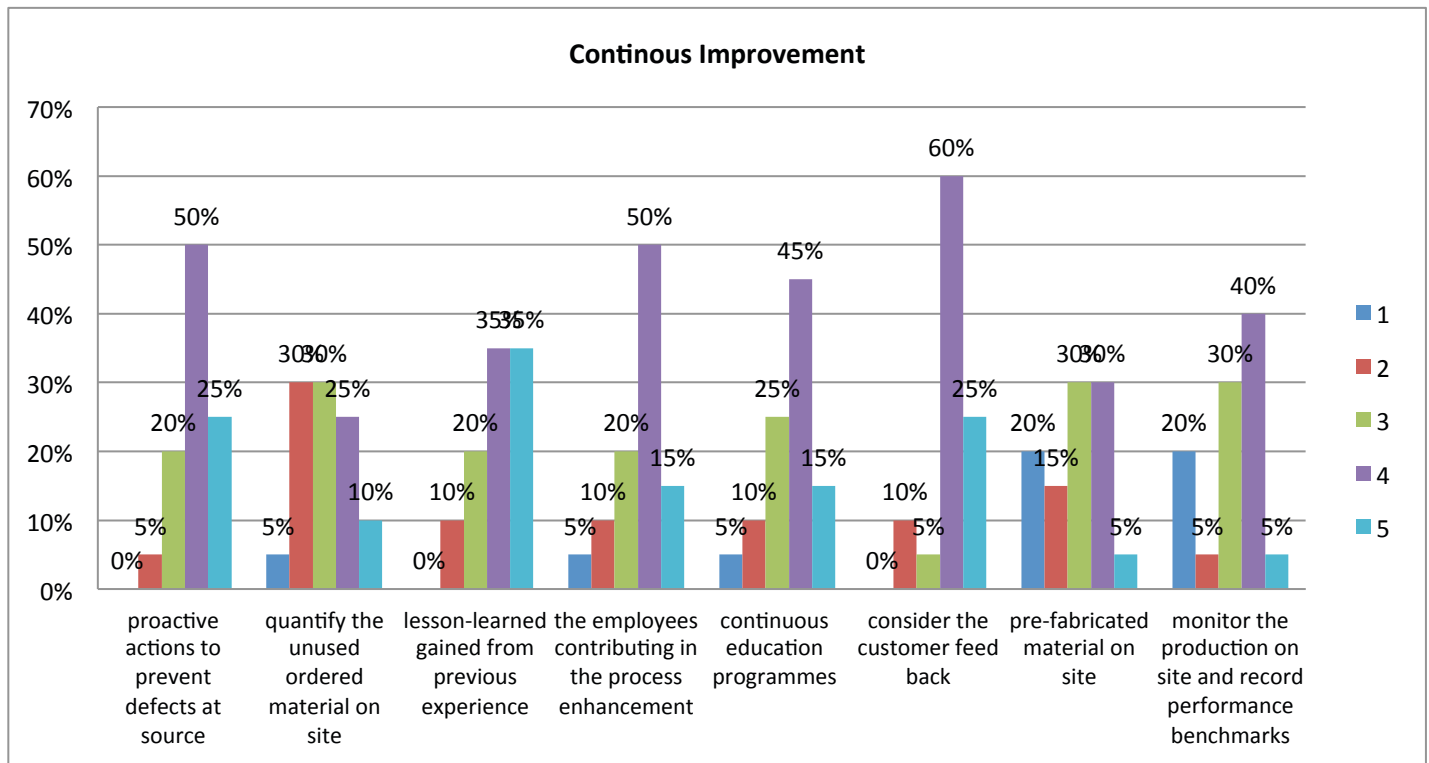


Figure3. 20 – Continuous Improvement

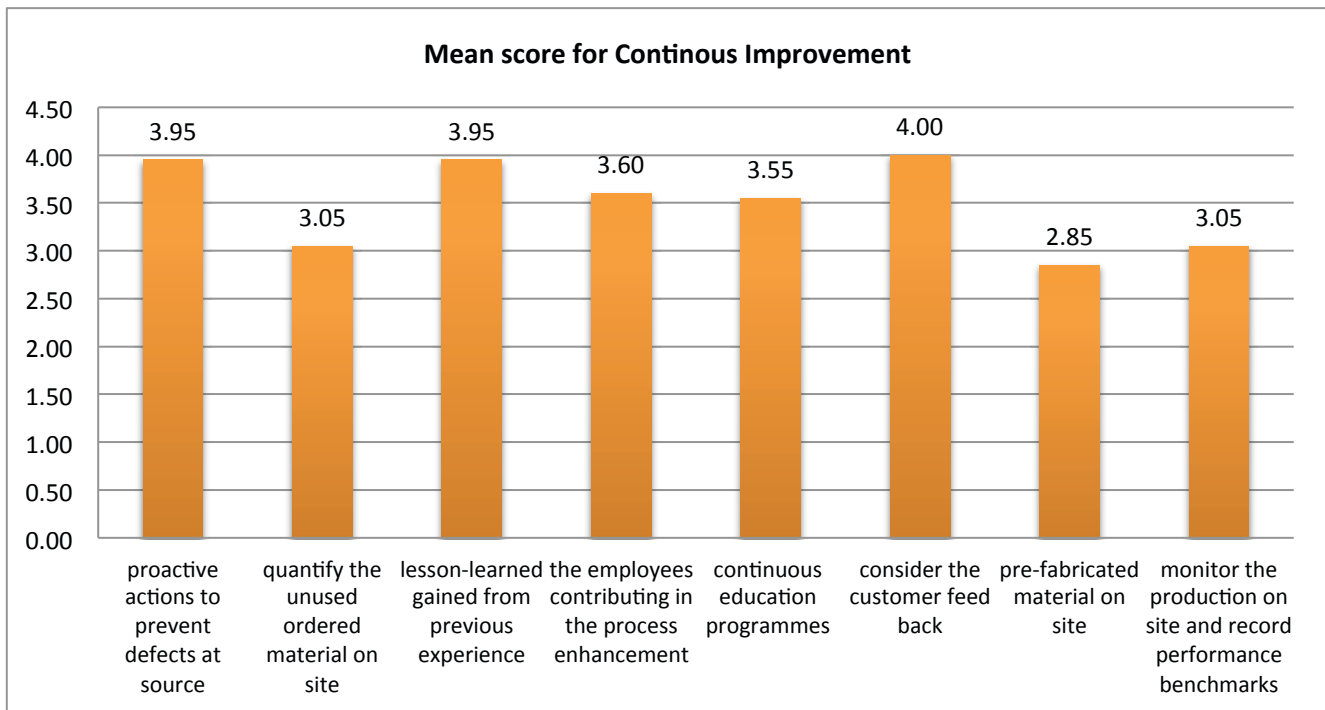


Figure 3. 21 – Mean score for Continuous Improvement

Process Variability

Fig. 3.22 shows the rating of each principle related to process variability on site in construction projects in Egypt. It can be concluded that more consideration should be given to the start of day meetings as 25% of the respondents are almost not adopting this method. Fig. 3.23 shows mean scores for each principle for the 20 respondents.

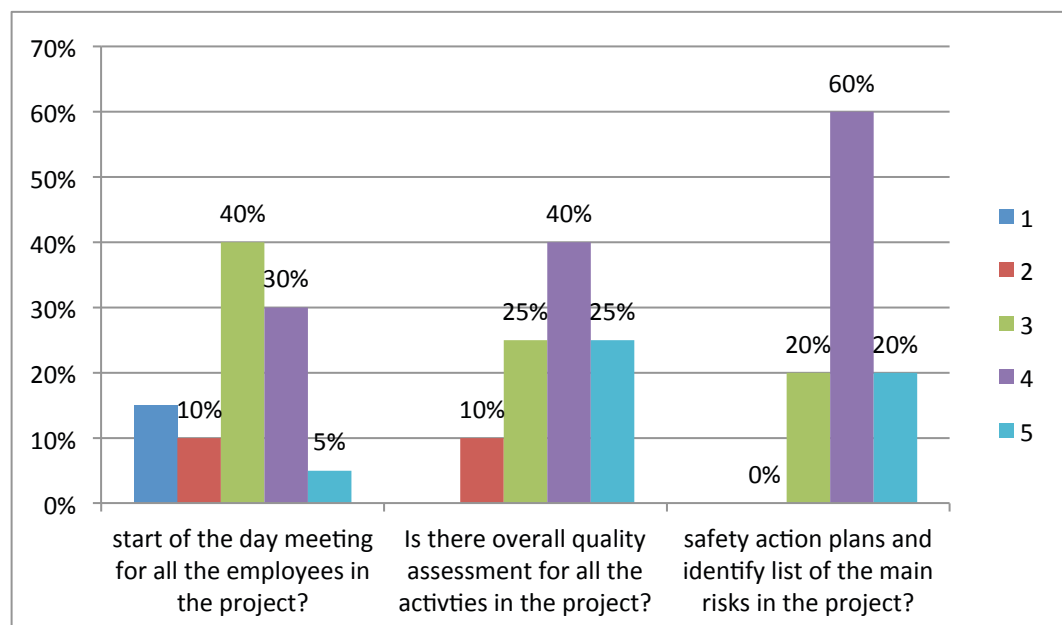


Figure 3. 22 – Process Variability

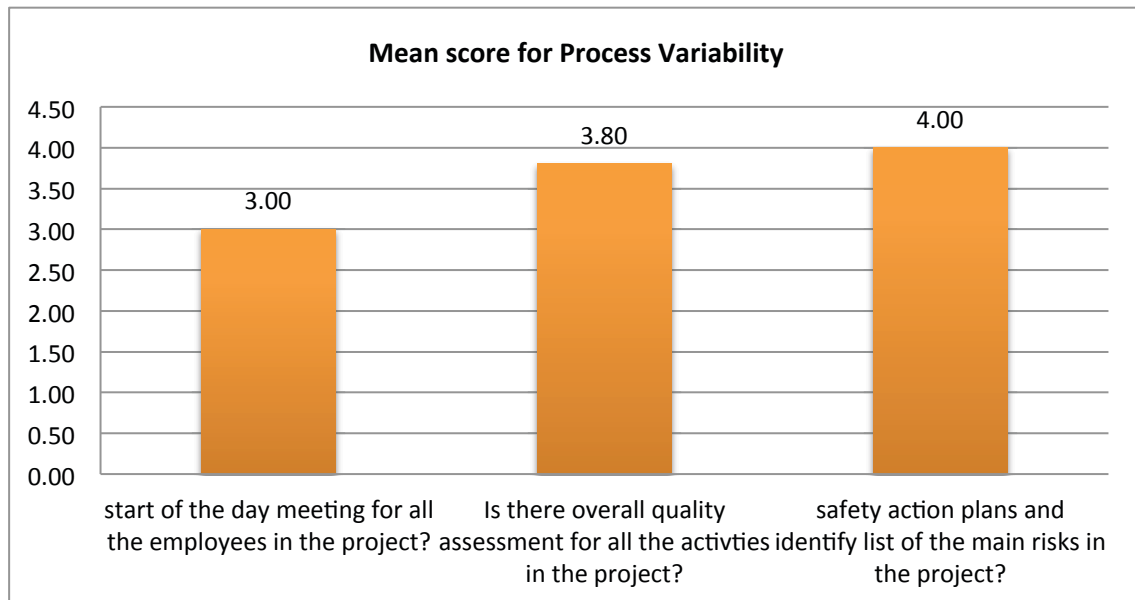


Figure 3. 23 – Mean score for Process Variability

Customer Focus

Fig. 3.24 shows the rating of each principle related to customer focus on site in construction projects in Egypt. It can be concluded that there are huge attention and consideration for the customer focus approach in most of the projects. Fig. 3.25 shows mean scores for each principle for the 20 respondents.

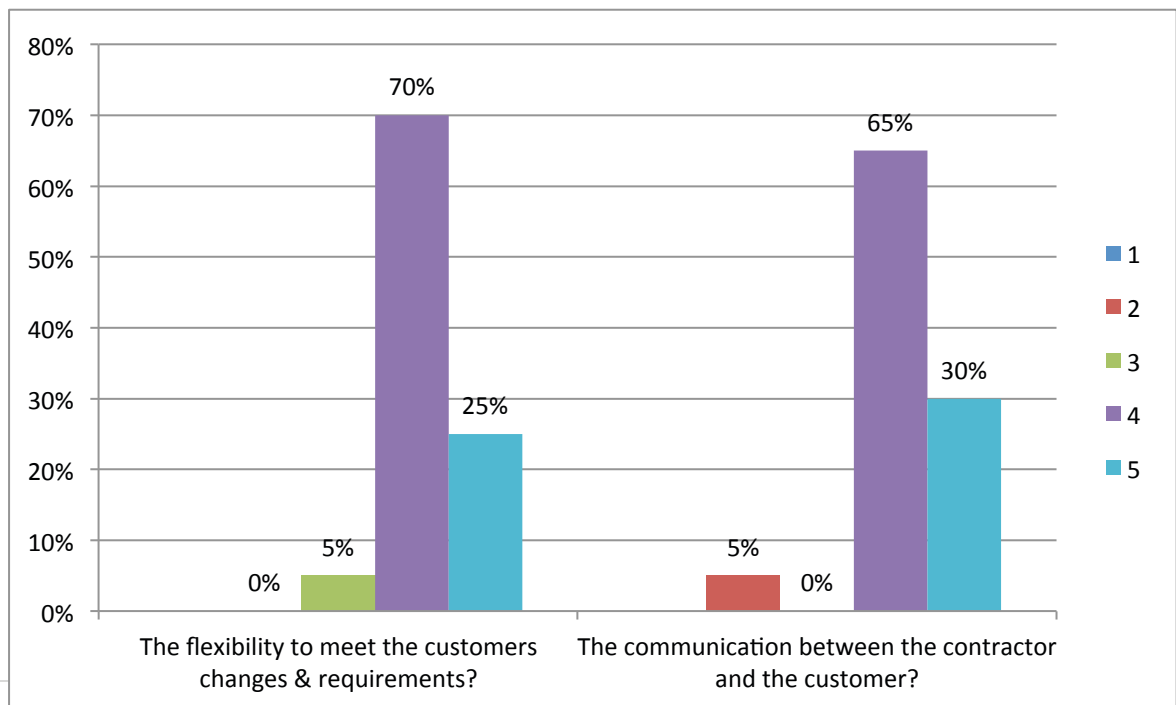


Figure 3. 24 – Customer Focus

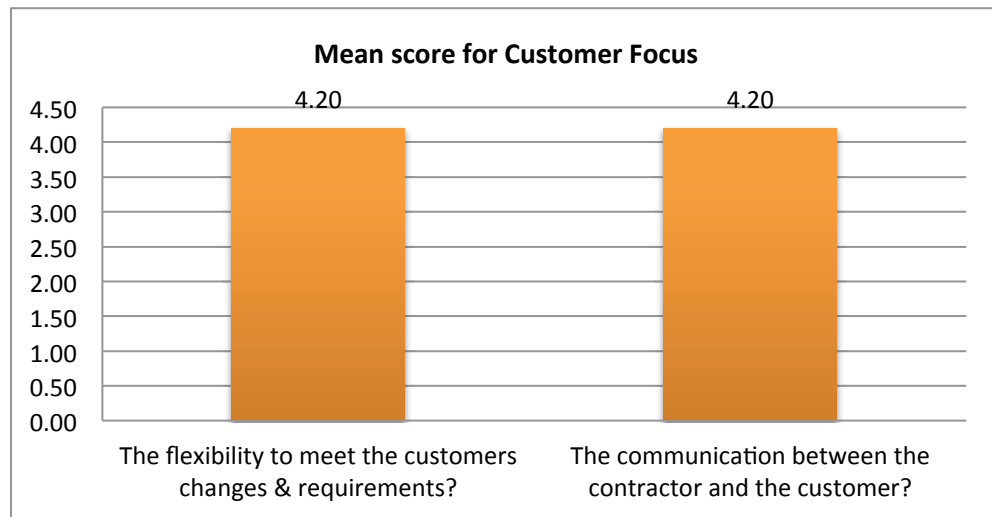


Figure 3. 25 – Mean score for Customer Focus

Visual Management

Question number 7 measured the awareness of the respondents about visual management. It can be concluded from the responses that the awareness of 65% of the respondents is average while 30% is low and are using it for safety related issues only as shown in figure 3.26.

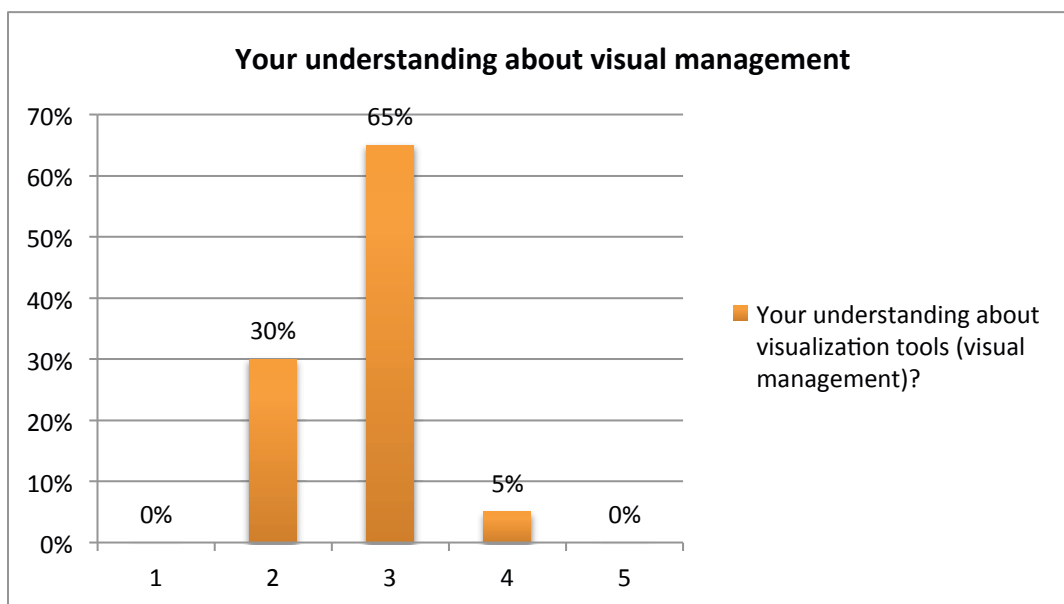


Figure3. 26 – Visual Management

Questionnaire Results and Findings

1. Factors Impacting Project Time

For the purpose of this thesis, the main focus will be on the causes of project delay or the factors impacting the project schedule. The ranking of the causes of Time overrun from the Contractor perspective is shown in Table 3.2. It can be concluded that more than 80% of the respondents believes that inadequate drawings, poor communication by contractor, change orders by owner, discrepancies in design documents, ineffective scheduling, and changes in material specifications during construction are the most factors causing delays and time overrun for a construction project. In the proposed framework, the focus will be in the aforementioned factors to show how using lean concept can avoid such delays.

Table 3. 2– Ranking of the causes of Time overrun

Factors Impacting the project Performance	Degree of severity (Impact) with frequency of occurrence >50%	Ranking by Severity
Change orders by owner	100%	1
Rework due to errors during construction,	94%	2
Poor site management and supervision by contractor	90%	3
Poor communication and coordination by contractor with other parties,	90%	4
Ineffective planning and scheduling of project by contractor	87%	5
Improper construction methods implemented by contractor	85%	6
Poor qualification of the contractor's technical staff,	83%	7
Mistakes and discrepancies in design documents,	80%	8
Un-use of advanced engineering design software and tools,	77%	9
Inadequate details in drawings,	76%	10
Complexity of project design,	76%	11
Delay in material delivery	75%	12
Changes in material types and specifications during construction	67%	13
Damage of sorted material while they are needed urgently,	67%	14
Unqualified workforce	58%	15
Low productivity of labors	55%	16
Site uncertainties	50%	17

2. Respondents' awareness about lean concept

The results showed that 55% of the respondents are not aware about lean concept and 45% of the respondents have scarcely aware of it. Being not well known in the Egyptian construction industry, the lean approach was examined in a case study for a project in Egypt to show its impact on the performance.

3. Implementation of Lean techniques/tools/principles in the Egyptian Construction Industry

Table 3.3 shows the all the lean techniques/tools with mean score less than 3.5. This score gives indication that these techniques are either not efficiently implemented or not totally implemented in the Egyptian construction industry. Therefore, these techniques should be examined in Egypt to see its impact on the project performance. In this research, the way of implementing such techniques and their effect will be shown in the case study.

Table 3.4 shows the all the lean techniques/tools with mean score more than 3.5. This score is an indicator for the level of implementation of these techniques in the Egyptian construction industry. These techniques are almost fully implemented and efficient and with some more effort their efficiency will be increased.

Table 3. 3 – Lean Principles/technique/tools to be efficiently deployed

Scope	Lean Principles/technique/tools to be efficiently deployed (Mean Score < 3.5)	Mean Score
Waste reduction	The concern to reduce the non-value added activities in the project	3.35
	The range of material waste in construction site	2.7
	The awareness of the employees about waste elimination	2.3
	The concern about unneeded movements when locating the inventory on site	3.45
	Material waste quantification	3
	Productivity loss quantification (labor/equipment)	2.6
Transparency	Visual management system at site	2.45
Flow Variability	visualization tools on site/project to improve work flow	2.15
	just-in-time method to decrease the volume of inventory on site	2.2
	collaboration with the suppliers to assure the delivery of material on time	3.3
	the work flexibility on site	1.75
Continuous	Quantification of the unused ordered material on site	3.05

Improvement	Pre-fabricated material on site	2.85
	Monitoring the production on site and record performance benchmarks	3.05
Process variability	start of the day meeting for all the employees in the project	3

Table 3. 4 – Lean Principles/technique/tools Semi/fully implemented

Scope	Lean Principles/technique/tools semi/fully implemented (Mean Score > 3.5)	Mean Score
Waste reduction	underutilized people on project considered as a waste	3.55
Reduce Variability	standardize the construction/design process	3.65
	communicate standard process to workers	3.65
	reviewing the design drawings at early stages	4.10
Transparency	Housekeeping on site	4.40
	Clarifying the whole method of construction to employees on site	3.80
	Communication channels with all the project stakeholders	3.95
Flow Variability	Schedule look-ahead to improve the work flow	3.95
	Management system to guarantee that the information flows smoothly	3.70
	The importance of the smooth of information, material and equipment on site	3.85
Continuous Improvement	Proactive actions or set quality plans to prevent defects at source	3.95
	the lesson-learned gained from your previous experience	3.95
	the employees contributing in the process enhancement	3.60
	Continuous education programmes or courses for the employees	3.55
	Consider the customer feedback to improve the process	4.00
Process Variability	Overall quality assessment for all the activities in the project?	3.80
	safety action plans and main risks identification in the project	4.00
Customer focus	The flexibility to meet the customer's changes & requirements	4.20

Based on the above lean tools/techniques classification, the lean tools/techniques that are implemented in the Egyptian construction projects will be examined in this research through applying it to a case study in a project in Egypt.

4. The potential of the respondents to use new management approach

55% of the respondents with experience more than 15 years have high potentials to use new management techniques/approaches while 30% of the respondents with experience above 10 years have average potentials. Only 10% of the respondents with experience between 5-10 years have low potential to use new management techniques.

Chapter Four

4. Lean Construction Framework

Lean concept has been introduced into the construction industry with varying levels of success for different projects at different countries. However, currently there are no practical guidelines for the application of the lean concept in the Egyptian construction industry.

This chapter introduces a proposed framework for the application of lean principles to enhance the Egyptian construction performance. This framework is considered a lean implementation guideline.

This framework was applied to a Case Study to see the potential improvements that lean can achieve. The main purpose of the case study is to show a real current process for the ready mix concrete works at a construction site in Egypt and to analyze the process. The main actual causes of delays and disruptions were also highlighted.

Before presenting the proposed Lean Construction Framework, the benefits achieved by using lean principles in different countries around the world will be addressed. It gives an indication with the potential improvements that can be achieved if lean approach was applied in construction projects in Egypt.

4.1 Benefits realized by Lean Construction implementation in different Countries

The construction industry has recently seen improvements in the projects performance in terms of value, quality, time and cost as a result of introducing lean thinking to the industry and using different lean techniques/principles. Lean thinking has proven to deliver tangible benefits to the performance and delivery of construction projects in different countries and organizations around the world.

Table 4.1 shows summary for the realized benefits achieved in different countries after

Country	% of improvement (Duration Reduction)	Used Lean techniques	References
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implementing lean construction approach. The main focus was on the implementation of lean principles in concrete works.

The improvements in the construction field in several countries around the world due to lean thinking have been reported in this research to develop a trend for lean benefits as shown in figure 4.1. The improvements achieved in Nigeria and Brazil, being developing countries, by applying Lean construction management can be taken as a guide for the improvements that lean approach can achieve in Egypt. Fig. 4.1 shows that the improvement accomplished by Brazil and Nigeria in reducing the project duration is 25% and 31% respectively. Hypothetically and due to the several similarities in their economic situation, Egypt can successfully implement lean construction and achieve similar results to those achieved in Brazil and Nigeria (IMF n.d.). This improvement will vary between 25% and 31%.

United States (US)	16%	Last Planner System, Visualization management & First run studies, 5S, and fail safe for quality & safety	(J. S. O. Salem 2005), (Turner 2013)
Brazil	25%	Last Planner System	(Conte 2002)
Nigeria	31%	Last Planner System, Visualization management & Huddle meetings	(Samalia Adamu 2012)
United Kingdom (UK)	37%	Just-in-time, collaborative planning, visual management, prefabricated material, Waste elimination, 5S, theory of constraints.	(Wodalski, et al. 2011), (Shires, Munn and Thompson 2005), (O'Connor and Swain 2013), (Smith 2013), (Ansell, et al. 2007), (BRE 2003)
Sweden	79%	Last Planner System, continuous improvement, Value Stream Mapping, Pull approach, reduce batch size, Just-in-time, collaboration, and prefabricated material.	(Simonsson, et al. 2012), (Eriksson 2010)

Table 4. 1 Countries Using Lean Approach in Construction & the realized benefits (performance Improvement)

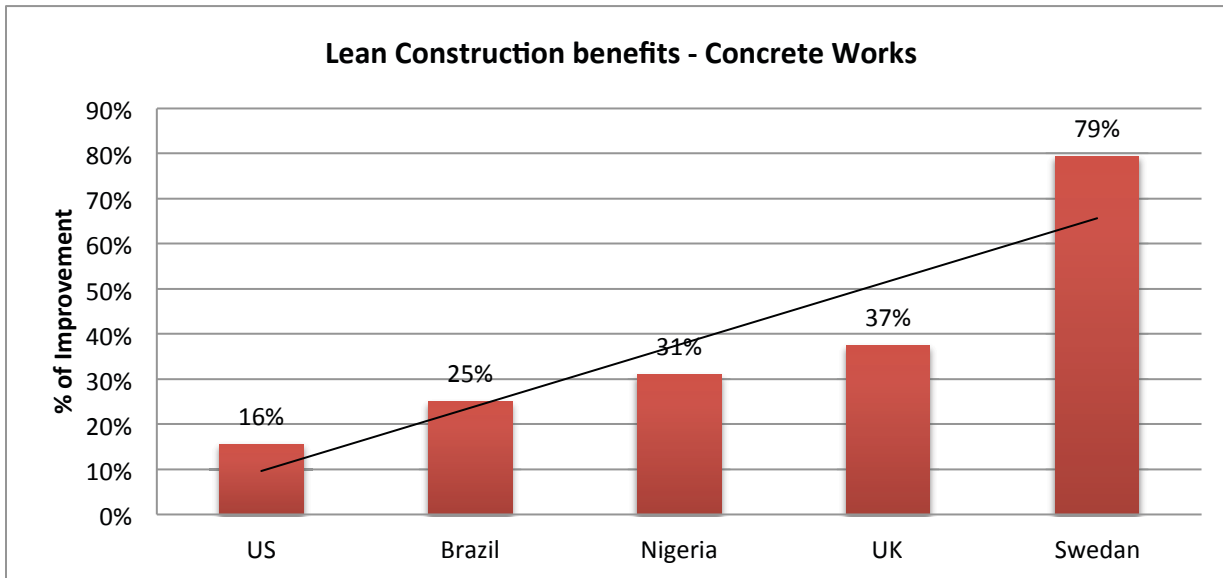


Figure 4. 1 - Countries Using Lean Approach in Construction & the realized performance Improvement

4.2 Proposed Lean Construction Management Framework

A Framework was developed to show the impact of applying certain lean principles on the project performance, especially, project duration. It can be considered as a way to proactively control the construction projects in terms of time, cost & quality. The guidelines presented in this framework depends more on feed forward method than feedback ones. In contrary to the traditional project control approach, the proposed Lean Construction Framework presents a proactive approach in controlling time, cost and quality. The proposed framework showed the practical guide lines that can be followed in order for the lean thinking to be appropriately applied to the construction industry.

4.2.1 Framework Foundation

The proposed framework presented in this chapter was established after an extensive research in several directions. The foundation of this framework is based on the following (see fig.4.2):

1. Literature survey

All the previous works show the impact of using lean management approach in projects outside Egypt as illustrated in chapter 2 of this research.

2. Questionnaire

The results of the questionnaire conducted as shown in chapter 3 of this research showed the following:

- a. The unawareness of engineers in Egypt about the lean concepts (55% of the respondents have not any idea about lean and 45% of the respondents have heard about it)
- b. More effort should be done to increase the awareness of employees on site about waste reduction and the concern to reduce the non-added value activities should be improved.
- c. The unawareness of engineers' in Egypt with the visualization management (30% of the respondents are scarcely using it while 65% are using it for safety issues only)
- d. Work flow should be improved by using several techniques that are not familiar to the construction industry in Egypt such as Just-in-time technique and flexibility
- e. The potential of the respondents to use new management approach (55% of the respondents have high potential to use new management techniques)
- f. The causes of disruptions and the factors impacting the overall performance of the project were also measured through the questionnaire. Previous studies have shown that tremendous improvements for these disruptions can be achieved by adopting lean approach.

3. Theoretical framework of traditional project control

The role of traditional Project Control approach in controlling the projects corresponds to a reactive approach more than a proactive one where actions are only taken after the problems are appeared instead of preventing their occurrence. The controller (cost or time) records the variance or feedback signals on the variables (activities duration/cost) we wish to control. Then the variance/deviation between the planned and actual performance is measured and the control is implemented by taking the corrective action in an attempt to reduce the deviation. Fig. 4.3 shows the traditional control approach as introduced in the PMBOK® Guide, 4th Edition

However, the proactive approach or the feed forward could be found in the mindset of the lean construction. The feed-forward approach emphasizes on controlling the inputs (resources that flow into the process) and on removing any obstacles from the execution process to ensure smooth flow of process execution. This approach prevents problems from occurrence rather than having to cure them later (Merschbrock 2009).

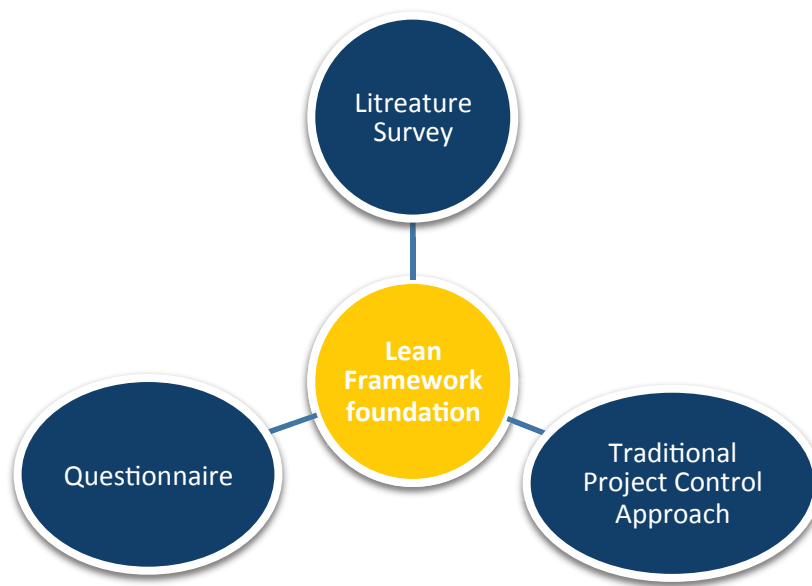


Figure 4. 2 – Lean Framework Foundation

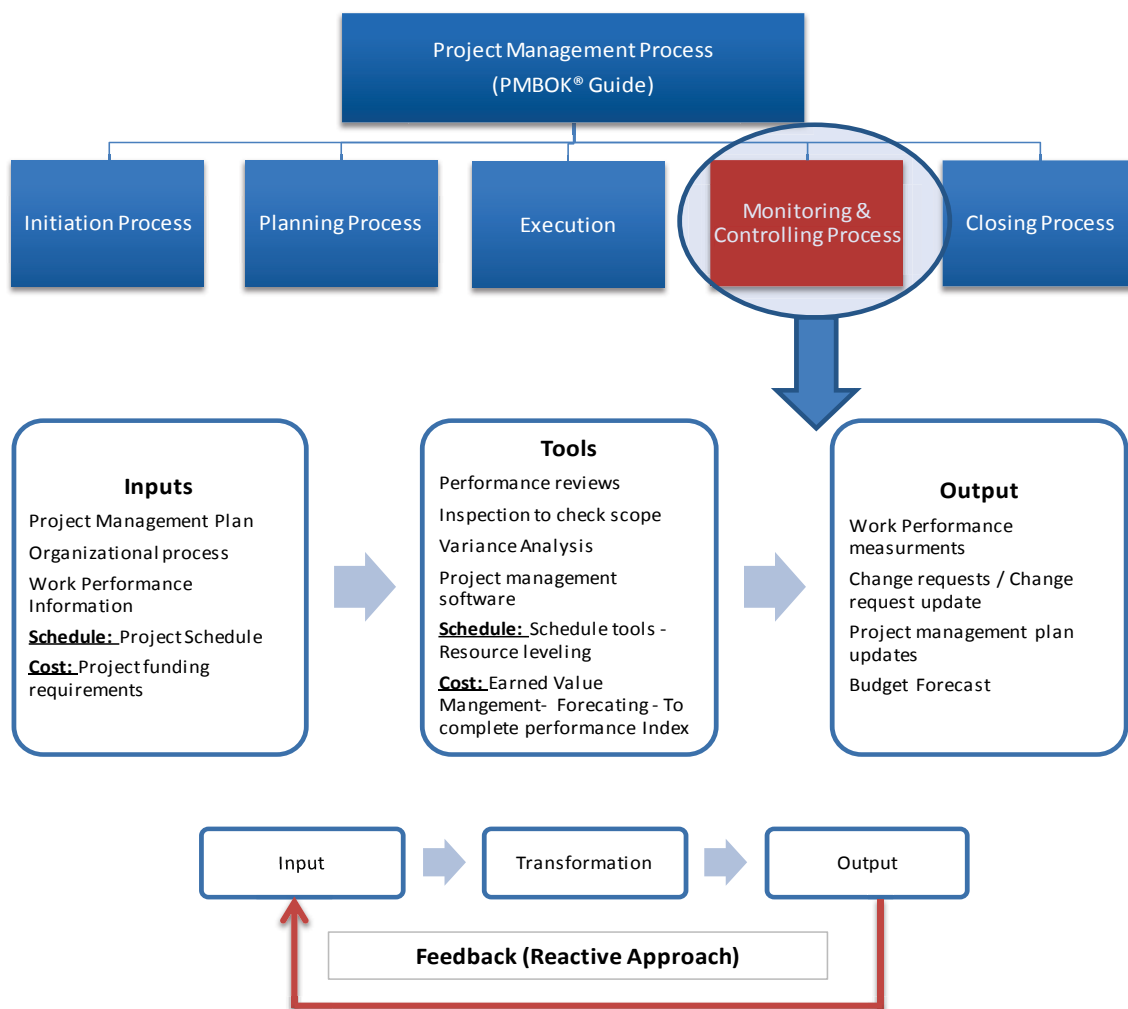


Figure 4. 3– Traditional Project Control process (PMBOK® Guide, 4th Edition)

Based on the above framework foundations, proposed guidelines for the lean management approach are established. The following guidelines are generic and can be applied to any type of work. The proposed lean construction management framework consists of six steps (See Fig.4.4):

1) Process Map for the activities

Develop a process map for all the activities in a construction project to show the sequence and the important steps in order to achieve the project deliverables. In this research, the main focus was on the ready mix concrete works starting from the preparation (preconstruction) phase and till pouring the concrete on site.

2) Establishing the Current state Map

Current state mapping (CSM) is typically used to map the existing project process as it is actually operating. The main purpose of the map is to provide a clear view of where wastes exist, such as delays, disruptions, bottlenecks, non-‘right first time’ quality, or excessive processes etc. CSM stipulates the basis for developing an improved future state process (O’Connor and Swain 2013). For the purpose of this research, a current state map should be established and all the existing activities and their durations are to be plotted. This includes the Value Added, Non-value added and the Essential non-added value activities.

3) Waste Reduction/Elimination

Construction waste is classified into two main groups namely the physical and non-physical waste. The physical wastes include solid and material waste while the non-physical wastes include the time and cost overrun (Nagapan, Rahman and Asmi 2012). The waste reduction/elimination in this research was done through three main steps:

3.1 Waste Identification

Identifying the wastes in the process in accordance with eight types of wastes introduced in the literature as follows (Garrett and Lee 2011):

- Overproduction (e.g. materials or services not needed)
- Waiting (e.g. employees waiting for equipment to finish)
- Transportation (e.g. unnecessary transport of goods)
- Unnecessary processes
- Inventory (e.g. goods awaiting processing or use)
- Unneeded movement (e.g. people or labor unneeded movements)
- Defects (e.g. in materials / finished installation)

- Underutilized people

3.2 Waste Analysis

After identifying the wastes in the process, the wastes should be analyzed and classified. The types of the activities (value added activities, Non Value added activities, and Essential Non Added value activities) should be determined and its impact on the overall process performance should be measured.

3.3 Fishbone analysis (also known as cause and effect)

It is a visual brainstorming process to identify the main causes of the delays, disruptions and/or any causes that contribute to the problem (O'Connor and Swain 2013).

4) Lean tools/techniques selection to be used for construction improvement

The main purpose of the proposed Framework is to apply the five key principles of the Lean approach to the construction projects in Egypt. These principles are (more details about the principles/techniques are shown in chapter 2):

1. Identify Customer Value
2. Map the Value Stream (operations that generate the value)
3. Make the product flow, waiting is waste
4. Use a pull logistic
5. Seek perfection in all operations

To adequately implement the above principles, the appropriate lean tools/techniques should be chosen to improve the current process. These techniques/principles will be selected based on the following criteria:

- The limiting constraints surrounded by the project and if these constraints can be changed or not.
- The applications of these tools and their efficiency based on data collected from the literature.

5) Developing the Future State Map (Ongoing projects)

Future state mapping (FSM) is typically developed to map a process after incorporating Lean principles so that work flows efficiently through streamlined processes. Appropriate Lean tools are then used to support the implementation of the improved process (e.g. problem solving, 5S, visual management etc...) (O'Connor and Swain 2013). For the purpose of this research, a future state map is established after eliminating wastes and after incorporating the appropriate lean techniques/tools to improve the work flow of the process. This includes elimination of the bottle necks and avoiding any causes of future delays. The future map is usually constrained by the current condition of the project; therefore, it is a method for improving the process within the limiting constraints of the project. Accordingly, the future map is the enhanced version of the existing current state of the project.

6) Developing the ideal State Map (New or future Projects)

For new starting projects, an ideal state map can be established based on previous experience from the historical data from previous projects. The future maps used in previous projects can be used as guideline for the new similar projects to avoid any inconvenience in the new projects. This can be done through adapting the conditions of the new projects and make it more flexible to accept the lean approach.

4.2.1 Framework Limitation

1. The proposed Lean Construction Framework is limited to complex, uncertain and fast track projects. The project complexity can be defined as “consisting of many varied interrelated parts and can be operationalized in terms of differentiation and interdependency” (Baccarini 1996). The project is considered to be complex when the project behaviors and outcomes are difficult to predict and explain. Complex projects consist of multiple interdependencies and nonlinear relationships (Howick, Ackermann and Williams 2009).
2. The proposed Lean Construction Framework in this study is generic and can be applied to any type of work. However, the research results are based on one case study that only attributable and restricted to certain type of projects. Therefore, the features for some of the Framework guidelines will be adopted according to the project type, yet, following the same procedures of the framework. The selected lean technique and the results of the waste analysis are the main items that will

differ according to the type of the project, yet resulting in different future and ideal maps.

3. The acceptance of adopting this Framework in any construction firm is quite challenging. The company strategy and way of management plays a crucial role in accepting such new techniques. To successfully implement any new technique in a company, the top management has to accept and appreciate this new practice. Therefore, the "top- down" management approach should be adopted while developing an implementation strategy to new systems in the company to ensure the successful execution of these systems. This includes providing training to all the work team to increase their awareness about lean concepts to make the whole process more efficient.

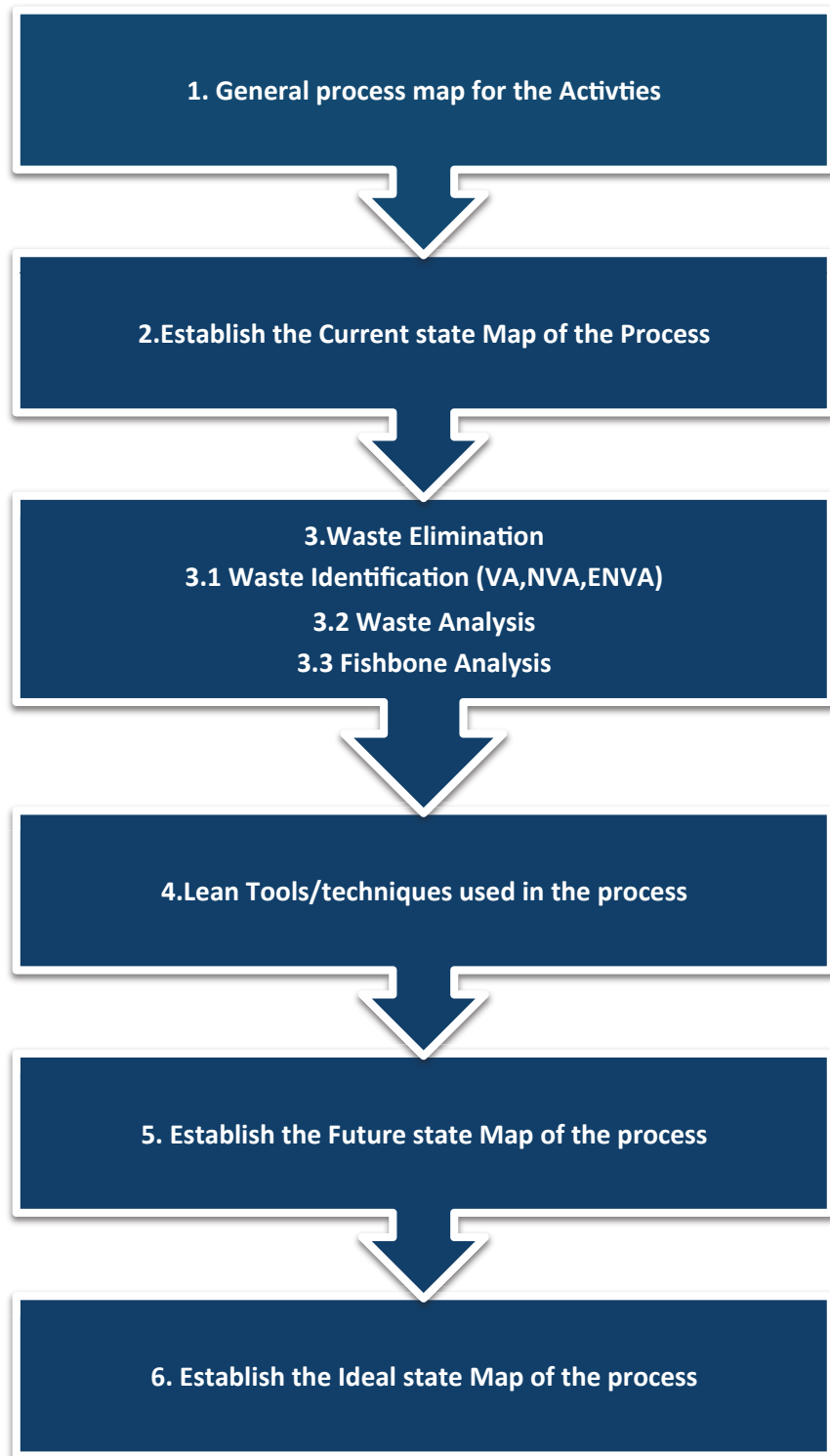


Figure 4. 4 - Proposed Lean Construction Framework

4.3 Lean Construction Framework Verification: A Case Study

The research objective is to show the impact of applying the lean approach through the proposed framework on construction projects in Egypt. Case studies would be a suitable way to study and investigate the current management approach in projects (Merschbrock 2009).

This research uses a case study approach to gather data. This data shows the current work activities and map the real process of ready mix concrete work activities of construction project for one of the largest construction firms in Egypt. The data collected in this research includes the durations for all relevant activities of concrete works (execution and pre-execution phase) in the project as well as analysis to all the causes of delays and disruptions. Also, the case study is vital for analyzing the actual durations and work sequence in the real life that each activity can take and see the effect of applying the lean thinking in changing the sequence and reducing the activities' durations. The durations of these activities can vary from project to the other, however and for the purpose of this research, this gives an idea of how we can control a project by using the lean approach. This case study can be regarded as a representative sample for the ready mix concrete work execution in most projects.

Case study description

The project is an existing Hotel located near downtown in Cairo, Egypt. It consists of one existing building and three new buildings: swimming pool, Garage area and Ballroom. Table 4.2 shows the project data. The research will focus on the ready mix concrete process of the Garage Area. The garage area was divided into 3 main zones for execution purposes as per the agreed method statement (see figure 4.5).

Table 4. 2 – Case Study data

Item	Description
Project Type	Building
Project Value	80 M EGP
Contract Type	Remeasured/FIDIC 87/Design-Bid-Build
Scope of Work	Concrete Works/Steel structure
Project Duration	9 months
Garage Duration Only	7 months

Building Type	Description
Existing Hotel Building	No. of rooms: 352 - 40487 m2 No. of floors: 12 floors
Swimming Pool & Cabanas	No. of Cabanas: 17
Garage Area	No. of floors: 1 Area: 9000 m2 Concrete Quantity: 12,000 m3
Ballroom	No. of floors: 3

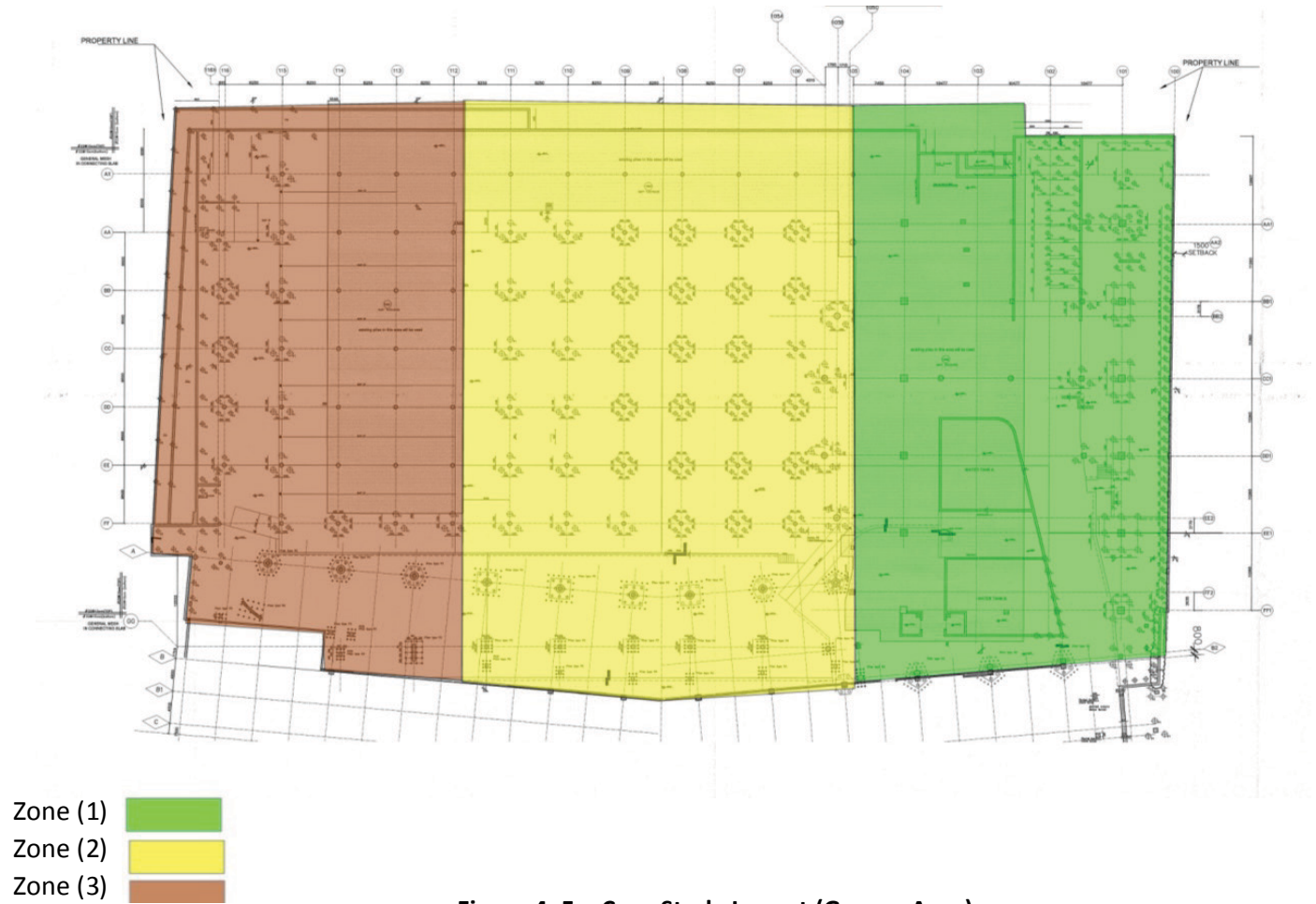


Figure 4. 5 – Case Study Layout (Garage Area)

4.3.1 Application of Lean Construction Framework on the Case Study

The framework as mentioned in the beginning of the chapter consists of 6 steps. These steps were derived for the case study as follows:

1) Process Map for the activities

Figure 4.6 shows the process map of the activities. The process was divided into 3 main phases as follows:

1. Preparation works include:
 - The shop drawings process
 - Material submittal process
 - Quantity surveying process
 - Purchasing Process
2. Material (Rebar) Delivery & fabrication include:
 - Rebar delivery
 - Rebar inspection
 - Loading/unloading of Rebar
 - Rebar fabrication
 - Material movements on site
3. Execution process include:
 - Concrete works for foundations of the Garage Area
 - Concrete Works for the Raft of the Garage Area
 - Concrete Works for the Retaining walls of the Garage Area

In this Case Study, the Monitoring and control process was highlighted in the process map. The project was over budget and behind schedule due to the passive attribute of the traditional project control process. The reasons behind the time and cost overrun were mainly due to the following reasons:

- The long time taken by the Engineer/owner to approve the Baseline schedule which hinders the Contractor from updating the schedule properly
- The method of control based on the monthly updates of the schedule and the budget which means that the corrective actions are taken after the problem

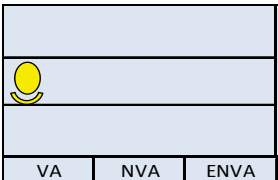




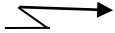
occurrence by one month leading to successive delays in the other project activities.


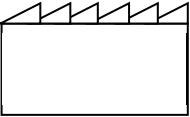
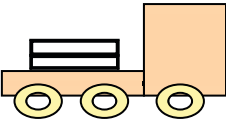


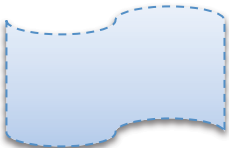
- The passive nature of the project control which highlights the problem after its occurrence (e.g. realizing that the completion date was delayed after the monthly update or that there are losses in the project after updating the monthly cost report). No actions were taken to prevent the occurrence of the problem and no appropriate analysis was done for the root causes of the problem to avoid it in the future. It was all about instant solutions for the problems.

2) Establishing the Current state Map

Based on the above process for the different work phases, a current state map was established and all the existing activities and its durations were plotted including the Value Added, Non-value added and the Essential non-added value activities. The main purpose of the value stream process is to identify the wastes and its main causes, thus, reducing these wastes. Current state maps were developed for the above highlighted three phases of construction. Figure 4.7, 4.8 and 4.9 show the current state maps for the three phases studied in this research which includes the activity name, duration, type, and no. of workers. Table 4.3 presents the list of symbols used in this thesis for the development of the state map.

Table 4. 3 – Value Stream Mapping Symbols

Symbol	Name and Meaning
	<p>Procedure: represents an activity or work to be done and the type of the activity (VA, NVA, ENVA)</p> <p> : Number of workers</p>
	Waiting
	Decision Node
	Connector: represents a flow relationship
	Electronic Information Flow

Symbol	Name and Meaning
	Pull (e.g. from Store)
	Supplier
	Truck
	Inventory
	This highlights improvement needs at a specific process that is critical to achieving the future or ideal state map (lean tools used)
	This highlights actions that should be taken to implement the lean tools/techniques

The main purpose of the value stream mapping is to highlight the potential improvements that can be done in certain activities to reduce waste and make the process more efficient. It can be considered as a decision support system for the project manager in which he can decide his priorities in solving the project's problems. This map can assist the management team on two issues: 1) To identify the value added and non-added value activities in the main process and try to improve the efficiency and decrease the durations of these activities 2) To improve the performance of the disrupted durations whether these activities is value added or non-value added activities.

The following are the work phases of the concrete works as shown in the current state maps:

I. Preparation Works:

- The planned and actual durations of the activities in the preparation phase was collected from the approved Baseline schedules and by interviewing the concerned engineers. The data was limited to part of the concrete works, namely the foundation works which include the footings, connecting slabs, raft and Retaining walls. Table 4.4

shows the actual and planned duration for all the related activities. The total planned and actual duration due to concurrency between the activities are 74 and 144 respectively.

- To develop current state map, both the actual and the planned durations should be identified and the root causes of the delays and disruptions should be investigated and analyzed in addition to the process map. Figure 4.7 shows the current process for the preparation phase and all the related stakeholders. The preparation works mean the work required to be done before issuing purchase orders and starting execution. The activities included in this phase usually impact the overall duration of the project.

Table 4. 4 - Durations for the preparation phase activities

Act. No.	Activities	Planned Dur.*	Actual Dur.*	Pred.	Succ.	Remarks
I.1	Receiving IFC dwgs (waiting period)	5	26		I.7	All the concrete drawings of Area 3
I.2	Assigning Team (time taken to assign team)	7	26		I.3,I.7,I.11,I.13	Assign technical team for the Shop drawings & take off
I.3	Developing Supplier list (Time taken)	3	8	I.2	I.4	For the rebar works only
I.4	send the specs to the suppliers to get the offers	5	5	I.3	I.5	For the rebar works only
I.5	Receiving Quotations (waiting time)	5	5	I.4	I.6	For the rebar works only
I.6	Contract agreement with the Supplier/Subcontractor	5	10	I.5	I.14	For the rebar works only
I.7	Shop Drawings submission for concrete and steel rft foundations (Conc. Qty = 2000 m3)	30	40	I.1,I.2	I.8	For the rebar, formwork
I.8	Shop drawings approval for concrete and steel rft foundations (Conc. Qty = 2000 m3)	34	40	I.7	I.9	For the rebar & formwork
I.9	Shop Drawings resubmission	0	21	I.8	I.10	For the rebar & formwork
I.10	Shop drawings final approval	0	14	I.9		For the rebar & formwork
I.11	Material Submittal	7	15	I.2	I.12	For the rebar

Act. No.	Activities	Planned Dur.*	Actual Dur.*	Pred.	Succ.	Remarks
I.12	Material resubmission & Approval	21	21	I.11	I.14	For the rebar
I.13	Take off (time taken) for Concrete works for foundations (Conc. Qty = 2000 m3)	12	30	I.7	I.14	For the rebar works only
I.14	Issue PO for Formwork & Rebar	3	3	I.6,I.12,I.13	II.1	For the rebar works only
Total Durations		74	144			

**Planned Duration: Durations from the approved Baseline Schedule of the project*

**Actual Duration: Durations from the updated schedule of the project*

II. Material delivery/on-site transportation

- The planned and actual durations of the activities in the Material delivery/On-site transportation phase was collected from the approved Baseline schedules and by interviewing the concerned engineers. The data was limited to part of the concrete works, namely the rebar of the foundation works which include the footings, connecting slabs, raft and Retaining walls. The flow unit of the current map is 50 Ton of Rebar, hence, all the durations based on this flow unit. Table 4.5 shows the actual and planned duration of all the related activities.
- This phase is part of the execution phase but it is vital to be elaborated as it includes several activities that add no value to the execution process. The flow unit of this process is the material, namely steel rebar. It shows the work flow of the material on-site. Figure 4.8 shows the current process for the Material delivery/On-site transportation phase.

Table 4. 5 – Durations for the material delivery/on-site transportation phase

Act. No.	Activities	Planned Dur.*	Actual Dur.*	Pred.	Succ.	Remarks
II.1	Prepare Storage	2	5		II.5, II.6	For storing 50 Ton of rebar
II.2	Install Mobile Crane (Rented)	1	2		II.4	
II.3	Inspect the delivered Material	0.25	0.5		II.4	Qty = 50 Ton

Act. No.	Activities	Planned Dur.*	Actual Dur.*	Pred.	Succ.	Remarks
II.4	Unload the material and move it to the Storage area	0.125	0.375	II.3	II.5	Qty = 50 Ton
II.5	Sort the Material in the store	0.625	1	II.4	II.6	Qty = 50 Ton
II.6	Update the inventory list	0.125	0.125	II.5		
II.7	Prepare the workshop	5	8		II.8	For all the project
II.8	Install the equipment and tools (Rebar Bender and cutter)	2	4	II.7	II.13	For all the project
II.9	Loading Material to move it to Workshop	0.125	0.375	II.5	II.10	Qty = 50 Ton
II.10	Movements from storage area to site Workshop	0.125	0.25	II.9	II.11	Qty = 50 Ton
II.11	Unloading Material to workshop	0.125	0.25	II.10	II.12,II.13	Qty = 50 Ton
II.12	Provide the steel foeman with the shop drawings to start fabrication	1	3	II.7, II.8	II.13	Qty = 50 Ton
II.13	Fabrication of Steel	5	10	II.12	II.14	Qty = 50 Ton
II.14	Loading of material to move to Site	0.125	0.25	II.13	II.15	Qty = 50 Ton
II.15	Movements from Workshop to site	0.125	0.25	II.14	II.16	Qty = 50 Ton
II.16	unloading material on site	0.125	0.25	II.15		Qty = 50 Ton
	Total Durations	15.75	29.75			

**Planned Duration: Durations from the site engineer's experience*

**Actual Duration: Durations from the site daily reports*

III. Execution Phase

- The planned and actual durations of the activities in the execution phase was collected from the approved Baseline schedules and by interviewing the concerned engineers. The data was limited to part of the concrete works, namely the foundation works which include the footings, connecting slabs, raft and Retaining walls. Table 4.5 shows the actual and planned duration of all the related activities.
- The current state map of the execution process of the concrete works includes the following main activities:
 - Reinforced Concrete Footings
 - Reinforced Concrete raft
 - Reinforced Concrete Walls (Retaining Walls)

The durations and sequence of these activities were mapped in the current state map showed in figure 4.9. The map shows the sequence of work in one cycle. This map should be repeated for every cycle to be more efficient but for the sake of this research we focused only on one cycle as the main purpose is to show how the works flow. All the relevant stakeholders are shown in the map and its relation with the activities.

Table 4. 6 – Durations for the activities of the execution phase

Act. No.	Activities	Planned Dur.*	Actual Dur.*	Pred.	Succ.	Remarks
III.1	Installation of FW for foundations/Cycle	1.5	5		III.2	Concrete Qtys/ cycle= 100 m3
III.2	Inspection/Cycle	0.25	4	III.1	III.3	
III.3	Installation of rebar work for foundations/Cycle	5	10	III.2	III.4	Steel Rft qtys/Cycle= 15 Ton
III.4	Inspection/Cycle	0.375	3	III.3	III.5	
III.5	Pouring Concrete	1	2	III.4	III.6	Concrete Qtys/ cycle= 100 m3
III.6	Waiting till removing the FW	4	8	III.5	III.7	
III.7	Removal of FW	1	5	III.6	III.8	
III.8	Transporting the removed FW to another works	0.125	1	III.7		
III.9	FW for Raft/cycle	2	25	III.5	III.10	Concrete Qtys/ cycle= 230 m3
III.10	Inspection	0.5	4	III.9	III.11	
III.11	1st layer of rebar work for raft	5	20	III.10	III.12	Steel Rft qtys/Cycle= 17.25 Ton
III.12	Inspection	0.375	4	III.11	III.13	
III.13	2nd Layer of rebar work for raft	5	20	III.12	III.14	Steel Rft qtys/Cycle= 17.25 Ton
III.14	Inspection	0.375	4	III.13	III.15	
III.15	Pouring Concrete	2	12	III.14	III.16	Concrete Qtys/ cycle= 230 m3
III.16	unloading Wall FW on site and FW assembly	0.125	6	III.15	III.17	
III.17	FW for Retaining walls/cycle (27 LM, H= 6, W=0.3)	4	12	III.16	III.18	Concrete Qtys/ cycle= 50 m3
III.18	Inspection/Cycle	0.375	2	III.17	III.19	
III.19	RFT for Retaining walls/cycle	4	10	III.18	III.20	Steel Rft qtys/Cycle= 7.5 Ton
III.20	Inspection for steel Rft/cycle	0.125	0.5	III.19	III.21	
III.21	Pouring Concrete (1st level)	0.5	2	III.20	III.22	Concrete Qtys/ cycle= 25 m3
III.22	Pouring Concrete (2nd level)	0.5	2	III.21		Concrete Qtys/ cycle= 25 m3
	Total Durations	38.125	161.5			

** Planned Duration: Durations from the approved Baseline Schedule of the project*

**Actual Duration: Durations from the updated schedule of the project*